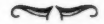
Transactions

of the

American Fisheries Society



SEVENTY-FIRST ANNUAL MEETING

St. Louis, Missouri

August 25 and 26, 1941

Published Annually by the Society

Washington, D. C.

1942

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EDITED BY THE COMMITTEE ON PUBLICATIONS FOR 1941-1942

H. J. DEASON, *Chairman*

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AMERICAN FISHERIES SOCIETY

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THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fishery problems.

OFFICERS FOR 1940-1941

President.....JAMES BROWN, Frankfort, Ky.
First Vice-President.....JOHN VAN OOSTEN, Ann Arbor, Mich.
Second Vice-President.....JOE HOGAN, Lonoke, Ark.
Secretary-Treasurer.....R. P. HUNTER, Hartford, Conn.
Librarian.....KENNETH E. COBB, Windsor Locks, Conn.

VICE-PRESIDENTS OF DIVISIONS

Fish Culture.....JOHN GOTTSCHALK, Indianapolis, Ind.
Aquatic Biology and Physics.....W. C. HERRINGTON, Arlington, Mass.
Commercial Fishing.....B. M. BRENNAN, Seattle, Wash.
Protection and Legislation.....ARTHUR L. CLARK, Jefferson City, Mo.
Angling.....J. A. RODD, Ottawa, Ont.

OFFICERS FOR 1941-1942*

President.....JOHN VAN OOSTEN, Ann Arbor, Mich.
First Vice-President.....JOE HOGAN, Lonoke, Ark.
Second Vice-President.....H. H. MACKAY, Toronto, Ont.
Secretary-Treasurer.....R. P. HUNTER, Hartford, Conn.
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Librarian.....KENNETH E. COBB, Windsor Locks, Conn.

VICE-PRESIDENTS OF DIVISIONS

Fish Culture.....JAMES R. SIMON, Cheyenne, Wyo.
Aquatic Biology and Physics.....R. W. ESCHMEYER, Norris, Tenn.
Commercial Fishing.....W. L. SCOFIELD, Terminal Island, Calif.
Protection and Legislation.....WILLIAM C. ADAMS, Albany, N. Y.
Angling.....CARL D. SHOEMAKER, Washington, D. C.

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*For street address see membership list.

STANDING COMMITTEES, 1941-1942[1]

Executive Committee

The Executive Committee consists of the president, vice-presidents, secretary-treasurer, vice-presidents of divisions, and James Brown, the president last year.

Committee of International Relations

William C. Harrington, *Chairman*	Arlington, Mass.
A. G. Huntsman	Toronto, Ont., Canada
Charles E. Jackson	Washington, D. C.
A. L. Pritchard	Nanaimo, B. C., Canada
William J. Tucker	Austin, Texas
F. A. Westerman	Lansing, Mich.
E. L. Wicklff	Columbus, Ohio

Committee on State and National Relations

Arthur L. Clark, *Chairman*	Jefferson City, Mo.
C. N. Feast	Denver, Colo.
John Gottschalk	Indianapolis, Ind.
Fred J. McCormac	New Orleans, La.
Frank B. Wire	Portland, Ore.

Committee on the Common and Scientific Names of Fishes

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W. A. Clemens	Nanaimo, B. C., Canada
John R. Dymond	Toronto, Ont., Canada
Samuel F. Hildebrand	Washington, D. C.
Carl L. Hubbs	Ann Arbor, Mich.
George S. Myers	Stanford University, Calif.
Leonard P. Schultz	Washington, D. C.

[1]Elected by the membership.

SPECIAL COMMITTEE[2]

COMMITTEE ON POLLUTION STUDY

KENNETH A. REID, *Chairman* ..... Chicago, Ill.
CARL D. SHOEMAKER, *Secretary* ..... Washington, D. C.
SETH GORDON ..... Harrisburg, Pa.
FRANCIS P. GRIFFITHS ..... Corvallis, Ore.
A. S. HAZZARD ..... Ann Arbor, Mich.
S. B. LOCKE ..... Boston, Mass.
EMMELINE MOORE ..... Albany, N. Y.
JAMES A. RODD ..... Ottawa, Ont.
M. W. SMITH ..... St. Andrews, N. B.

[2]Appointed by the President-elect, in accordance with a motion adopted by the membership.

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36.	E. A. Birge	1906-1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907-1908	Erie, Pa.
38.	Tarleton H. Bean	1908-1909	Washington, D. C.
39.	Seymour Bower	1909-1910	Toledo, Ohio
40.	William E. Meehan	1910-1911	New York, N. Y.
41.	S. F. Fullerton	1911-1912	St. Louis, Mo.
42.	Charles H. Townsend	1912-1913	Denver, Colo.
43.	Henry B. Ward	1913-1914	Boston, Mass.
44.	Daniel B. Fearing	1914-1915	Washington, D. C.
45.	Jacob Reighard	1915-1916	San Francisco, Calif.
46.	George W. Field	1916-1917	New Orleans, La.
47.	Henry O'Malley	1917-1918	St. Paul, Minn.
48.	M. L. Alexander	1918-1919	New York, N. Y.
49.	Carlos Avery	1919-1920	Louisville, Ky.
50.	Nathan R. Buller	1920-1921	Ottawa, Canada
51.	William E. Barber	1921-1922	Allentown, Pa.
52.	Glen C. Leach	1922-1923	Madison, Wis.
53.	George C. Embody	1923-1924	St. Louis, Mo.
54.	Eben W. Cobb	1924-1925	Quebec, Canada
55.	Charles O. Hayford	1925-1926	Denver, Colo.
56.	John W. Titcomb	1926-1927	Mobile, Ala.
57.	Emmeline Moore	1927-1928	Hartford, Conn.
58.	C. F. Culler	1928-1929	Seattle, Wash.
59.	David L. Belding	1929-1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930-1931	Toronto, Canada
61.	James A. Rodd	1931-1932	Hot Springs, Ark.
62.	H. S. Davis	1932-1933	Baltimore, Md.
63.	Fred A. Westerman	1933-1934	Columbus, Ohio
64.	E. L. Wickliff	1934-1935	Montreal, Canada
65.	Frank T. Bell	1935-1936	Tulsa, Okla.
66.	A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67.	I. T. Quinn	1937-1938	Mexico City, Mexico
68.	Fred J. Foster	1938-1939	Asheville, N. C.
69.	T. H. Langlois	1939-1940	San Francisco, Calif.
70.	James Brown	1940-1941	Toronto, Canada
71.	John Van Oosten	1941-1942	St. Louis, Mo.

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PART I
BUSINESS SESSIONS

TRANSACTIONS

of the Seventy-first Annual Meeting of the

AMERICAN FISHERIES SOCIETY

Saint Louis, Missouri

August 25 and 26, 1941

The Seventy-first Annual Meeting of the American Fisheries Society convened at 9:30 a.m., August 25, 1941, at the Hotel Statler, Saint Louis, Missouri, the President, James Brown, of New Orleans, Louisiana, presiding.

The meetings were held in cooperation with the Thirty-fifth Annual Convention of the International Association of Game, Fish and Conservation Commissioners.

The registered attendance of members, delegates and guests was as follows:

Registered Members in Attendance

Adams, William C., New York
Aldrich, A. D., Oklahoma
Alderson, I. T., Missouri

Bagley, Lester, Wyoming (Rep. Wyo. Game & Fish Com.)
Bailliere, Lawrence, Missouri
Ball, Robert C., Michigan
Bangham, R. V., Ohio
Beckman, William C., Michigan
Bennett, George W., Illinois
Bode, I. T., Missouri
Brown, C. J. D., Michigan
Brown, James, Louisiana

Carbine, William F., Michigan
Chute, Walter H., Illinois
Clark, Arthur L., Missouri
Clark, O. H., Jr., Michigan
Cobb, Kenneth E., Connecticut
Cooper, Mrs. Pat, Georgia (Rep. Ga. Division of Wildlife.)
Culler, C. F., Minnesota

Davis, George W., Vermont
Day, Albert M., District of Columbia
Deason, H. J., District of Columbia
DeGruchy, James, Oklahoma
Denmead, Garner W., Maryland (Rep. Md. Game & Inland Fish Com.)
Denmead, Talbott, District of Columbia

Eschmeyer, R. W., Tennessee

Feast, C. N., Colorado

Gentry, Glen, Tennessee
Gordon, Seth, Pennsylvania
Gottschalk, John, Indiana
Graham, Edward H., Maryland
Graves, David N., Arkansas
Gray, T. D., West Virginia (Rep. W. Va. Game Com.)
Greenbank, John, Michigan
Gutermuth, C. R., Indiana

Hayford, Charles O., New Jersey
Henn, Arthur W., Pennsylvania
Herndon, G. B., Missouri
Higgins, Elmer, District of Columbia
Hodges, W. H., Jr., Louisiana (Rep. La. Dept. of Conservation.)
Hoffmaster, P. J., Michigan
Hogan, Joe, Arkansas
Howell, Henry H., Alabama
Hubbs, Carl L., Michigan
Hunter, R. P., Connecticut

Jackson, Charles E., District of Columbia
James, C. C., Georgia
James, Hinton, North Carolina (Rep. N. C. Dept. of Conservation & Development.)

King, Willis, North Carolina

Langlois, T. H., Ohio
Leach, Glen C., District of Columbia
LeCompte, E. Lee, Maryland
Ledbetter, J., Oklahoma (Rep. Okla. Game & Fish Com.)
Leonard, J. W., Michigan
Lytle, W. H., Nebraska (Rep. Neb. Game, Forestation & Parks Com.)

Maclay, D. J., Montana
Markus, Henry C., Massachusetts
Meehean, O. Lloyd, Florida

Miller, George P., California (Rep. Calif. Fish & Game Com.)
Miller, L. F., Alabama
Morse, L. Glen, Kansas

O'Donnell, John D., Wisconsin
Osborne, Livingston, Illinois (Rep. Ill. Dept. of Conservation.)

Poe, J. Charles, Tennessee (Rep. Tenn. Dept. of Conservation.)
Posekany, Lewis, Wisconsin

Quee, Ethel M., District of Columbia (Rep. American Wildlife Institute.)

Rahilly, Joseph, Michigan (Rep. Conservation Com.)
Reid, Kenneth A., Illinois
Roach, Lee S., Ohio
Rodd, J. A., Ontario

Schneberger, Edward, Wisconsin
Schwob, F. H., Iowa (Rep. Iowa Conservation Com.)
Shawhan, H., West Virginia
Shields, A. R., Tennessee
Shoemaker, Carl D., District of Columbia
Shoup, Charles S., Tennessee
Simon, J. R., Wyoming
Smith, E. V., Alabama
Smith, L. L., Jr., Minnesota
Soulen, G. H., Texas
Stephens, E. S., Missouri (Rep. Mo. Conservation Com.)
Stone, G. E., Missouri (Rep. Mo. Conservation Com.)
Surber, E. W., West Virgina
Swingle, H. S., Alabama

Tarzwell, Clarence M., Alabama
Taylor, D. J., Ontario (Rep. Ont. Dept. of Game & Fisheries.)
Thompson, Fred A., New Mexico
Thorpe, Lyle M., Connecticut
Trautman, Milton B., Ohio
Tucker, Will, Texas

Van Oosten, John, Michigan

Warfel, H. E., New Hampshire
Westerman, Fred A., Michigan
Wire, F. B., Oregon (Rep. Ore. Game Com.)
Wright, Stillman, Utah

Young, Earl C., Ontario

Registered Guests in Attendance

Amos, Alice, Missouri
Anderson, B. M., Missouri
Andrews, J. D., Wisconsin

Baker, C. C., Tennessee
Barmeier, Harry, Missouri
Barnickol, P. G., Missouri
Behrens, Lavere, Missouri
Bennett, L. H., Minnesota
Bennett, Vernon, Missouri
Beñtz, Frank L., Maryland
Berry, Guy, Missouri
Bloz, John, Georgia
Braunum, Rudolph, Missouri
Brokaw, William, Missouri
Brown, Paul V., Nebraska
Brubaker, Helen, Missouri
Bruton, Harry, Missouri
Buford, W. C., Missouri

Callison, Charles, Missouri
Campbell, J. S., Louisiana
Capps, F. O., Missouri
Case, Wilfred C., Missouri
Chance, Charles, Tennessee
Chapman, Katherine, Missouri
Chapman, M. K., Missouri
Charles, Mary Jane, Missouri
Churchill, Warren, Illinois
Clover, H. W., Missouri
Coogan, F. J., Louisiana
Corey, C., Missouri

Darling, J. N., Iowa
Decker, Adelaide, Missouri
Dunlap, Mrs. M. N., Missouri
Dunlap, M. N., Missouri

Ellis, W. W., Missouri
Findley, John D., North Carolina
Fisher, John, Jr., Tennessee
Forsythe, E. S., Saskatchewan
Foster, Glenn R., Nebraska
Frisbie, Reed, Missouri
Frohne, W. C., Missouri
Frost, A. A., Missouri

Gabrielson, Ira N., District of Columbia
Gallagher, Hubert, Illinois
Gillham, C. E., Illinois
Gowanloch, James N., Louisiana
Graves, Dave N., Arkansas
Graves, Mary Beth, Missouri
Gray, Wallace, Missouri
Green, Joe E., Missouri
Greensfelder, A. P., Missouri

Hammer, Ralph, Maryland
Hammett, A. R., Jr., Missouri
Hansen, Donald, Illinois
Hesen, J. W., West Virgina
Hicks, Kenneth R., Missouri
Hoerr, Roland M., Missouri
Hornbuckle, Bettye, Missouri
Hunt, Francis D., Illinois
Huston, T. W., Iowa

Jeffery, Lisle, Missouri
Johnson, Beckwith, Missouri
Johnson, Cave, Missouri
Jones, J. W., Tennessee

Keener, G. D., Jr., Tennessee
Kopplin, E. M., Missouri

McCormac, Fred J., Louisiana
McGehee, L. E., Missouri
McGimpsey, M. H., Missouri
McGloskey, John G., Louisiana

McGuirk, LeRoy, Oklahoma
Masters, Benton, Missouri
Mayes, E. A., Missouri
Morris, A. G., Missouri
Morrison, H. E., Missouri
Morrow, Jay, Missouri
Murphree, M. M., Oklahoma
Myrick, Sterling, Missouri

Nagel, W. O., Missouri
Neu, Arthur J., New Jersey
Newman, Nelson H., Oklahoma
Noble, W. G., Missouri

Olson, Herman, Wisconsin

Pascal, Thomas R., Missouri
Peyton, J. H., Tennessee
Pittenger, Glenn D., Missouri
Plattner, Harry, Missouri

Ranney, R. G., Missouri
Ringo, Mary Nan, Missouri
Robb, Dunbar, Missouri
Roberts, Asbury, Missouri

Shantz, H. L., District of Columbia
Simon, Don, Louisiana
Sparks, Robert C., Missouri
Speaker, E. B., Iowa
Stegeman, Lucille, Missouri

Terrill, Harold V., Missouri
Turney, George, Missouri

Van Cleve, Richard, California
Van Engel, Willard A., Wisconsin
Veatch, Cecil, Missouri
Von Limbath, Bruno, Illinois

Walker, C. H., Indiana
Weber, J. S., Missouri
Weyer, Albert E.
White, George, Missouri
Wiebe, A. H., Tennessee
Winkelmann, Gerry, Missouri
Wolfenson, Louis, Missouri
Worthington, Robert, Missouri

OPENING REMARKS

JAMES BROWN, PRESIDENT

The seventy-first annual meeting of the American Fisheries Society is now opening with a somewhat different type of program than has usually been scheduled. Some may consider the change from a formal program of presenting papers to a program devoted to informal round-table discussions quite radical. Your Executive Committee, at a meeting held at Memphis last February adopted this new type of program because of the expressed opinions of a great many members that they were not obtaining the maximum benefits from attending our meetings. This feeling has increased during the last few years because the large number of papers on the program has limited the amount of time available for discussion, or has made discussion impossible. Sufficient time was not available at some meetings to permit all of the important papers to be read. Therefore I hope that everyone present will participate in the discussions and that we will enjoy good attendance at all of our sessions.

The new form of program will in no way alter our custom of publishing formal papers in the *Transactions*. Titles of a number of papers have been submitted to the Secretary who has had abstracts of them printed which will be distributed for your information. These papers will be considered for publication by the Committee on Publications under the same procedure followed in the past.

World conditions have changed radically since our last meeting and great responsibilities have fallen upon all of us as a result of these circumstances. The need for conserving our natural biological resources is more urgent than ever because of the increased demands that are being placed upon them to fill the economic and recreational requirements of a well-rounded program of National defense. Those trying days that lie ahead will demand the exercise of our best abilities and all our energy. Information and suggestions we can obtain and exchange at these meetings will be of great value in helping each of us successfully to protect the natural resources entrusted to his care.

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER
For the Year 1940-1941

R. P. HUNTER

During the past year there has been no active campaign for new members. However, many of our coworkers have been most helpful in bringing the work of the Society to the attention of their friends and associates. As a result of this, we have added 59 individuals (5 of whom had previously been members), 9 libraries and 6 State memberships. Two State commissions have reinstated their membership, making a total of 74 new members—substantially the same total as for the period 1939-1940. But I regret to inform you that our losses exceeded our gains. These losses comprised: 72 dropped for non-payment of dues; 12 resignations, and 9 through death—a total of 93. This is a little better showing than last year, when we reported a total loss of 113.

Our cash balance in the General Fund at the close of the 1940-1941 fiscal year was $435.46 with no outstanding indebtedness. In our Permanent Fund we had to our credit $1,141.56. The cash balance in the General Fund as of August 20, 1941, was $1,600.25 which indicates that since the close of the fiscal year membership dues have been coming in exceptionally well.

The chairman and members of the Committee on Publications are again to be commended on the excellent job of editing the seventieth volume of the *Transactions* and on getting the book off the press at a much earlier date than during the past few years. This volume was unusually large, 528 pages, costing the Society $2,006.81 for printing alone. Comparing the current volume with the one previous, there were 138 more pages at an additional cost of $915.93.

We have prepared a booklet containing the abstracts of papers submitted for presentation at this meeting. Two calls for abstracts were sent out in advance of the meeting with August 11 set as the last day for receiving copy. Twenty-one papers were received and the abstracts have been printed together with the North American Fish Policy to serve as a basis for some of the discussions scheduled at these meetings. Following the meeting copies of the abstracts will be sent to the members not present. It is hoped that the booklet of abstracts will provide a more prompt method of circulating information concerning the work of our members in advance of the publication of the *Transactions*.

I beg to submit the financial statement for the past fiscal year as follows:

TREASURER'S REPORT
July 1, 1940—June 30, 1941

GENERAL FUND

RECEIPTS			
Balance on hand July 1, 1940			$ 396.17
Annual dues			
Individuals:			
1939-1940		179.10	
1940-1941		1,188.70	
1941-1942		234.00	1,634.50
Libraries:			
For the year 1939-1940		18.00	
1940-1941		70.00	
1941-1942		13.00	101.00
For the year 1938-1939	$	32.70	

Clubs and Dealers:		
For the year 1938-1939	5.00	
1939-1940	5.00	
1940-1941	105.00	
1941-1942	30.00	145.00
State Membership:		
For the year 1939-1940	180.00	
1940-1941	640.00	
1941-1942	40.00	860.00
Exchange on checks		.15
Sale of *Transactions*		228.84
Sale of reprints 1939 *Transactions*		233.50
Total receipts		$3,599.16

DISBURSEMENTS

Transactions:		
1938, Vol. 68		
Reprints		$ 14.97
1939, Vol. 69		
Reprints		327.55
1940, Vol. 70		
Printing	$2,010.23	
Editing	125.00	
Reporting	125.00	2,260.23
Clerical and secretarial expense:		
R. P. Hunter	100.00	
Ethel M. Quee	200.00	
Extra assistance	10.75	310.75
Postage		107.43
Office Supplies		19.51
Stationery and Printing		73.00
Rental safety deposit box		11.10
Exchange on checks		6.81
Express		8.64
Premium on bond		18.75
General expense		1.70
Telephone and telegraph		3.26
Total disbursements		$3,163.70
Total receipts General Fund	$3,599.16	
Total disbursements General Fund	3,163.70	435.46
Balance on hand, July 1, 1941	$ 435.46	
Balance in Petty Cash Fund	5.00	
Balance on hand July 1, 1941	$ 440.46	

PERMANENT FUND

RECEIPTS		
Balance on hand July 1, 1940		$ 608.68
Interest on Saving Account	$ 14.59	
Interest and principal Mortgage Certificates	488.29	
Dividends on Commonwealth Southern pfd.	30.00	532.88
Total		$1,141.56

DISBURSEMENTS

None	
Balance on hand, July 1, 1941	$1,141.56
Par value of certificates other than Government Bonds	5,000.00
Par value of 10 shares Commonwealth Southern pfd.	1,000.00
Par value of Government Bonds	1,650.00
Total	[1]$8,791.56

[1]The market value of Certificates during the past year has been far below par, but since there is no open market no established cash value is available. The cash value of the 10 shares of Commonwealth and Southern Preferred, par value $100.00, as of July 1, 1941, was $610.00.

LIST OF AMERICAN FISHERIES SOCIETY SECURITIES

A list of securities owned by the American Fisheries Society as of July 1, 1940, was published in the *Transactions*, Vol. 70, pp. 24-25. No changes in the holdings of the Society had occurred by June 30, 1941, and therefore the complete list is not published in this report of the Treasurer for the year 1940-1941.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE DIVISION OF FISH CULTURE

JOHN GOTTSCHALK

After reviewing statements of various officers of this Society during the past few years fish-culturists must recognize that the most significant trend in fish culture is an increasing doubt as to the ability of fish hatcheries to perform the task assigned to them. Ordinarily this task is merely a maintenance of adequate fishing conditions, the insuring of at least an adequate catch for the greatest possible number of fishermen. During the year just passed thinking along these lines has spread rapidly throughout most of the United States and Canada. No longer is it confined to the inner office discussions of fish-culturists and administrators, for we must know by now that large portions of the fishing public are questioning the continuation of mass plantings, if not urging the operation of hatcheries for those activities which now appear to give greater promise of success.

While some of the more glaring faults of common restocking practices have rightly been the subject of controversy among members of the profession for some time, the fact that we can now recognize a trend in the public thinking along these same lines, is sufficient cause to make fish culturists everywhere pause long enough for a conscientious review of the factors involved in this change in attitude, and to determine if possible the most progressive steps which may be taken before the public is aroused sufficiently to step in and take over.

The reason for this reversal of policy on the part of thoughtful fishery workers and the public, is not too difficult to understand. At least it will not be unintelligible if we can disassociate ourselves from the many superficial perplexities which have impeded the progress of fish culture. In most States people are fairly well acquainted with the size of fish that are stocked in their favorite fishing waters. It is not in the least unusual for them to go out a day or two before a fish delivery and find game fish, spawned and reared under purely natural conditions, as large or larger than the fish which are sent out from their nearby State or Federal fish hatchery. Every community has its interested workers who have assisted in planting the few cans of fish annually allocated to their local waters, and who have watched with misgivings the battalion of hungry black bass deployed around the planting site. Should an outsider decide to investigate the reference literature on fish culture he would wonder what the word "progress" means, when he can find statements of 30 years ago which coincide, almost word for word, with statements made during the past 5 years. From the annual reports and the newspaper publicity of the various fish and game departments people are aware of the tremendous numbers of fish which have been broadcast throughout the country without resulting in any definite improvement in fishing.

The controversy in which we now find ourselves embroiled, goes much further than the mere question of the efficiency of hatcheries in the propagation and distribution of fish. The issue is whether there is any actual necessity for the restocking of lakes and streams. The fact that many hatcheries have been inefficiently managed and that fish culture as a whole is behind the times is beside the point. Actually, arguments over efficiency, fry *vs.* fingerlings, fingerlings *vs.* adults, etc., have been a handicap. Too much of our attention has been diverted from the preparation for the acrimonious debate in which are now engaged, and which will doubtless continue for a long time.

A conservation program devoid of any fish propagation would be a strange one indeed and no such situation need develop. There are many fields in which hatcheries can play an important part; fields in which hatchery men will not

find themselves foreigners. There will continue to be a necessity for production of new species, which after adequate trial and experimentation, have been found to be both desirable and satisfactory for stocking. There will always be new water areas which will demand the output from hatcheries. Many hatchery ponds can be used profitably in the production of bait and forage minnows, both for distribution to fishermen, and to replenish those areas in streams and lakes in which the natural supply of these species has been depleted. As the march of a destructive civilization proceeds, there will be more and more locations in which natural spawning will be limited and which therefore, will offer the greatest advantage to hatchery-reared stock. In order to accomplish any of these aims, however, the fish-culturist must be able to go to the public and to the administrator with a frank admission of past mistakes and a fair evaluation of his ability, that he may organize and conduct a program which will meet the needs of the present. If he cannot find a task other than that of planting astronomical numbers of fish, in waters where they will be a waste or a detriment, he had better look for another job.

To those more or less radical elements that advocate management as the logical successor to a hatchery program which would be dissolved immediately, it need only be pointed out that the management still is in an experimental stage. Before administrators or the public will accept management as a substitute for hatcheries, these newer concepts must be tried and proved. In some cases they have been tested and the results have been as negative as the worst examples of hatchery malpractice.

Above all, administrators and fishery workers as a whole, must realize that the time to begin developing a public attitude of sympathetic cooperation is now. Every hatchery man, from the superintendent down to the pensioner who mows the grass, must make a strenuous and forthright effort to eliminate the many misconceptions which the public has concerning the stocking of fish as a remedy for all ills. The administrator must relieve the "figures" pressure and be willing to stand behind a well organized politics-free distribution program. The work of management agents must be correlated with that of the survey, research, and propagation personnel. There is a great future, and an enthusiastic public waiting for this kind of a program.

REPORT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

WILLIAM C. HERRINGTON

During the 12 months since our last meeting at Toronto, I have been laboring under the uncertain burdens of the Division of Aquatic Biology and Physics. The problems posed by "aquatic biology" I have found are not insuperable, but "physics" has me baffled. What field does it cover? I have inquired concerning its implications, but to no avail. Finally, I have been thrown back upon my own resources and forced to speculate.

It cannot refer to the usual field of physics, for I am afraid that this special sphere could receive only inadequate treatment in our hands. Possibly, it refers to the physics used in physical oceanography, but it seems rather strange to single out this one science associated with aquatic biology and so honor it above its numerous fellows. Consequently, I recommend to the members of this Society that unless further convincing evidence is forthcoming, they take action in respect to the name of this Division, along one of the following lines:

Drop the term "physics" and retain the title simply as "aquatic biology;" or if some think that these words by themselves render too much homage to the organic and too little to the physical, it might be changed to "aquatic biology and hydography." According to Webster, this complete title then would mean: "The science of life growing or being in water or frequenting the margins of

water and the description and study of seas, lakes, rivers, and other water bodies.'' Personally, I prefer the first simplified title, for in the present day the field of aquatic biology touches upon so many related sciences, that it would be impractical to attempt to include them all in any title. Furthermore, I believe that from the point of view of the members of the Society, the science of hydrography is of importance only as it helps us to understand the fish and its environment, and the same can be said for chemistry, statistics, geography, geology, and other related sciences.

So much for nomenclature! Now for the field of aquatic biology itself. I will make no attempt at a comprehensive review of progress in this field during the past year. To attempt to do so in a brief report such as this would be presumptious in view of the wide range of present fishery work, both geographically and in kind. The Division of Fishery Biology of the Fish and Wildlife Service, alone, lists 57 separate projects and 220 subprojects under way during 1941, ranging from fishways and fish screens to selective breeding of trout and management of offshore fish populations. If we add to this the extensive work being carried on by other countries in the Americas and by numerous State and private organizations, it is evident that present work in aquatic biology is impressive in its range and diversity.

Although I am sidestepping the major task of reviewing progress in this broad field, I would like to point out a few developments and trends which I believe are significant.

First of all, there is the effect of the war on fishery investigations. In European and Asiatic countries particularly, the supreme importance of immediate war problems necessarily has diverted attention and facilities from fishery work. This is reflected by the reduced number and size of publications now coming from these countries. As a consequence, we lack much of the stimulus and example derived in times of peace from contact and comparison with the work of leaders in the foreign field. Fortunately, however, fishery work in the Americas has sufficient range and merit so that we should be able to develop among ourselves a fair measure of stimulation through contacts made possible by organizations such as the American Fisheries Society and our fishery publications.

In view of the fate of scientific work in general and fishery science particularly in the belligerent countries, together with the present quasi-belligerent status of the United States and the probability of a protracted conflict and our increasing involvement, it would appear well worth while to devote considerable thought to a consideration of what action we can take in order that our work may avoid, at least partially, the fate of European science. Of course, some of us may defend a ''business-as-usual'' policy, but it seems very doubtful whether we could or should attempt business as usual in the present National emergency. If we attempt it, we may find eventually all or nearly all of our work, regardless of its relative importance, will be neatly labelled ''for future reference'' and filed away until such time as a less turbulent world will permit its resumption.

If we wish to escape this fate, what is our alternative to ''business as usual?'' To this there is no single answer for all of us, but perhaps our individual solutions may be discovered if we consider in what ways our scientific programs can be modified to contribute most to the National war effort. Possibly this contribution requires the diversion of much of our scientific facilities from programs with long-range objectives to problems offering promise of immediate practical contributions. The latter includes primarily those problems bearing on the immediate provision of more or better supplies of food at lower costs in time and equipment, but it also covers the development of methods and procedures which make it possible to perform our regular work and services with greater economy of time or material.

Such a modified program will stress applied science as against pure science, and the immediate return as against the remote, but through it all we must be sure that there be maintained the essential observations, records, and controls in

those cases where their temporary interruption would invalidate years of work and effort. To be sure, the unrestricted exploitation of some of our fishery resources would yield increased food supplies or recreational facilities the first year, but in most cases at the cost of greatly reduced yields during those following.

We all know the effect of the last war on the Alaska salmon fisheries. The results could be equally serious now for the halibut fishery of the Pacific, the lobster fishery of the Atlantic, or for any protected lake, pond, or stream fishery in which the population must have protection to permit a sustained yield. It would take a bold or inspired prophet to guarantee that the extra amount of food or recreation made possible by relaxed protection will not be more important one or two years from now than it is at present.

Likewise, the cessation of all biological observations and records of the fisheries would result in a considerable saving in time and effort, but in many cases at a high future cost. Where a continuous series of observations and records provides the basis for our understanding of the condition of the fish populations and the formation and modification of management measures, a temporary break in the records might result at worst, in almost irreparable damage to the stock of fish through uninformed management; or at best, in the invalidation of the results of many years of work.

By adequate planning for immediate contributions and some careful discrimination between what is essential and what is only desirable in our long-range programs, it may be that during the difficult years we have entered, our immediate contributions can be achieved without crippling our basic programs too seriously.

In the conventional field of aquatic biology and related sciences, I believe I detect certain trends which may be significant and should be encouraged.

In times past it seems to me that workers engaged in fish culture and in studies of fresh-water fish and of marine fish, pursued more or less independent courses, each group sufficient unto itself. Of late, these men increasingly are coming to acknowledge that their fields are continuous, in fact, that they overlap to a large extent. This trend in thought is particularly noticeable to those who during the past 10 years have participated in meetings of mixed groups of aquatic biologists. Fresh-water and marine workers are finding that the general problem of population management is the same in fresh and salt water, although the present points of attack may differ somewhat in detail. Study of populations in the open sea and in a small stream or pond may seem to be entirely different problems, but when the marine biologist studies the fish population of a small semi-enclosed portion of the sea and the fresh-water biologist the population of such water bodies as the Great Lakes, the tables are turned and it becomes clear that the terms "fresh-water" and "marine" biologist provide a purely superficial classification.

Because marine populations frequently are so extensive and their range without fixed boundaries, the marine worker has found a large portion of his effort directed to development and application of methods for accurately following the abundance of marine species and determining the causes of fluctuations in their abundance. Because fresh-water populations are more limited in extent and their habitats more circumscribed, the task of evaluating abundance has not been so preclusive of other work, with the result that a greater proportion of time and effort has been available for the study of food conditions, indivdual behavior, and habitat improvement. However, in both cases a knowledge of the population and its changes is essential to the development and understanding of management methods. From the beginning, the marine worker has had to use indirect sampling methods. The biologist on a small pond or stream found an apparent short cut involving the poisoning or seining of the entire population.

However, this method has a very limited application since it provides only a single, final picture of the population rather than a running record of the changes resulting from the application of different management methods. To obtain the latter information, the fresh-water worker now finds it desirable to resort to sampling methods similar to those forced by circumstance upon the student of open-sea populations. In general, as the present marine worker approaches his first fundamental objective, population measurement, he is finding more time for other studies necessary to understand the observed population, its behavior, and fluctuations. But even here the size and extent of his subject make progress slow.

In the fresh-water and marine field alike, it is coming to be acknowledged that the final test of the importance of any environmental factor, such as food, temperature, or fishing strain, is the reaction of the fish population to changes in these factors. To an increasing extent workers in both fields are recognizing the need for statistically well-designed and controlled experiments, which make definite conclusions accessible with the minimum of effort and material. Tests of the most efficient tagging and feeding methods and development of sampling programs, are examples of the field in which statistical design can be very helpful.

Another trend, present or potential, which this organization should encourage, is toward reconciliation of the viewpoints of the two schools of fish producers, those exponents of 100 per cent artificial propagation and exponents of 100 per cent natural propagation and water improvement. There should be no question but that a judicious mixture of the two is necessary in any enlightened fishery management program. The proportions may vary from 100 per cent natural propagation and spawning stock management in most marine fisheries and in fresh-water areas where conditions for natural propagation are favorable and the fishing drain relatively limited, to a major artificial propagation in areas with poor conditions for natural propagation and a heavy fishing drain, and with a fish sufficiently valuable commercially or recreationally to justify the expense. The sardine of the Pacific and the mackerel and haddock of the Atlantic are examples of species for which artificial propagation apparently can contribute no significant benefits, while the Columbia River salmon is an example of a species and situation for which artificial propagation is essential, at least temporarily. Fish culture also must be called upon to provide the nucleus needed for establishing stocks of fish in streams or areas from which they have been eradicated by man or natural catastrophe, and to provide the material for the introduction of species into new areas when it can be demonstrated that this is desirable. Biology and management must be called upon to provide the information necessary for the fish stocking policy and to furnish a continuous guide and check on the effect of the planting program. Restoration of Atlantic salmon in New England by natural reproduction and management exclusive of fish culture or by fish culture exclusive of management, would be a very long and doubtful undertaking. By the proper coordination of the two, restoration appears to be a current possibility, granted the availability of necessary facilities for the work.

It is true that the exponents of artificial propagation have made their mistakes in years past, but so too have the biologists. An individual case of useless or harmful planting does not prove that all artificial propagation is wasted. Neither do a few successful plantings justify an all-inclusive program of artificial propagation. When we can consider our fish production problems with a nonpartisan eye, and the value of a fully-coordinated attack is fully appreciated, we can expect the most rapid progress toward our objectives and greater appreciation and support from the public.

REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

ARTHUR L. CLARK

The fishery departments of the various States have been canvassed and requested to report upon the more significant legislation and other developments within their respective borders that have occurred since our last annual meeting and which, in their opinion, should be recorded in the *Transactions of the American Fisheries Society.*

The legislatures of four States, Alabama, Iowa, Kentucky, and Louisiana, were not in session during the year. Fourteen States reported that although their legislatures met no important changes in fishery legislation occurred. These were Arizona, Arkansas, Delaware, Florida, Idaho, Maine, Nebraska, North Dakota, Oregon, South Carolina, Utah, Virginia, Washington, and West Virginia. Important developments in the remaining States have been grouped and discussed under general subject headings.

Commercial Fisheries.—An increased interest in the striped bass or "rock" has developed in the eastern coastal States. Rhode Island and Massachusetts increased protection of the species by adopting a 16-inch minimum size limit (snout to the fork of the tail). Massachusetts prohibited the use of seins and traps set for the primary purpose of catching striped bass which is the first legislation in that State recognizing the species as a game fish. Pennsylvania prohibited the sale of striped bass less than 18 inches in length. Connecticut established a 12-inch limit and a catch limit of 10 fish for striped bass caught in inland waters, and a 16-inch limit (snout to fork of tail) for striped bass taken by commercial fishermen.

Further evidence of improved coordination between coastal States in the management of migratory fishes is shown by the ratification of the Atlantic States Marine Fisheries Compact by seven States: New Hampshire, Massachusetts, Rhode Island, New York, New Jersey, Delaware, and Maryland. The Atlantic States Marine Fisheries Commission will be organized as soon as the compact has been ratified by the Congress. Thus the machinery is set up, at last, for effective interstate cooperation and action in conserving, managing, and utilizing the marine fisheries of the east coast.

The State of New York enacted a law providing for management of the shad fishery of the Hudson River, which is similar to a measure previously enacted in New Jersey. The New York act grants to the Conservation Department complete regulatory control in the event that the shad fishery, recently restored, should decline subsequently.

Continued effort is being made by the States bordering the Great Lakes to bring about uniformity of regulations governing the fisheries, particularly those of Lakes Michigan and Superior. The continuing program has shown some progress toward the ultimate objective although there appear to have been no specific or outstanding developments during the past year.

Administration.—One of the important principles emphasized in the *American Fish Policy,* prepared and adopted by this Society, is that the State and Federal Departments responsible for the conservation and restoration of the fisheries should be granted discretionary power in regulating the harvest and in other management practices. That this principle is being recognized and adopted is reflected in the following developments: The Maryland legislature granted to the State Conservation Department full discretionary powers, including extension as well as restriction of seasons. The Connecticut State Board was granted authority to regulate length and creel limits for white and yellow perch in ponds or lakes "when found advisable." The New Hampshire commission was granted authority to make regulations establishing open and closed seasons for fishing and fixing maximum creel limits. The Ohio Division of Conservation and Natural Resources was granted broadened authority to permit regulation of the taking and posses-

sion of clams or mussels, crayfish, turtles, frogs, and aquatic insects as well as of fish and game.

In contrast to these constructive developments in the interest of conservation, we are impressed very unfavorably with numerous of the changes that have occurred in the administrative personnel of many States. An example of departure from the principles of the *American Fish Policy* is to be found in North Carolina where the Board of Conservation and Development was enlarged from 12 to 15 members. Although the board is organized into committees representing the several interests of the department, and the fishery interests are represented, a point which seems to have vital and adverse significance is that the term of office of the board members was altered to coincide with the term of the Governor. This alteration was approved by the legislature at the request of the Governor.

Management.—The Wisconsin Conservation Department, using its regulatory powers, is attempting to solve a problem in the northern lakes where fishing intensity is concentrated on larger fish, such as muskellunge, wall-eyed pike, and black basses, with little fishing for the smaller game fish such as yellow perch, bluegills, and crappies. Winter fishing activities have been limited to the smaller species and, in some instances, this appears to be resulting in better balanced fish populations.

The New York legislature provided a special license for muskellunge. Each license stipulates a seasonal limit, and 5 fish has been set as a maximum for Chatauqua Lake. Each special license holder is provided with a number of tags corresponding to the seasonal limit, which will provide a method of determining fishing pressure for the species. The act also contains other provisions designed to assist in the management of the muskellunge fishery which has been in the process of depletion for a number of years.

Miscellaneous.—The Colorado legislature appropriated $200,000 to the Fish and Game Department for use in the development of hatcheries and retaining ponds and for environmental improvement.

Indiana has accorded protection to the channel catfish for the first time by imposing a 10-inch size limit.

Michigan granted further protection to bluegills and sunfish by making them subject to the same closed season as black basses and by reducing the maximum catch limit from 25 to 15. Additional restrictions were imposed on the capture of minnows for commercial purposes and the capture of mayfly and other insect nymphs and larvae was restricted. The use of live goldfish or carp for bait was prohibited.

Minnesota increased the price of resident fishing licenses from 50 cents to 1 dollar, and 60 per cent of the money derived from the sale of licenses is to be devoted to fish propagation.

Wyoming revised legislation relative to fish ladders in irrigation diversions and fish ladders over dams to place responsibility for screening and ladder construction with the Game and Fish Department instead of the irrigator as formerly.

Illinois, North Carolina, Maryland, New Mexico, North Dakota, Oklahoma, and Vermont reported minor changes in fishing seasons and creel and size limits, most of which are constructively restrictive.

Federal Legislation.—Information concerning developments of National or international significance has been supplied by Talbott Denmead, Kenneth Reid, and James A. Rodd. No information was obtained from the Republic of Mexico and no important changes were reported for the Dominion of Canada.

In the United States, many bills have been proposed to Congress that would affect the fisheries, but none has been adopted up to the present time. The more important and familiar ones are the various pollution bills (discussed in the report of the Pollution Study Committee presented at this meeting) and the so-called Buck Bill (H.R. 3361) to provide for aid to the States in fish-restoration and management projects, patterned after the Pittman-Robertson Act for

wildlife. A bill introduced recently in both the House and the Senate (S. 1433, H.R. 4453) seeks to amend the Federal black bass law by including game fishes of all species. It is now in committee but passage during the present session of Congress is improbable.

A number of bills have been introduced as items in the National defense program, including several new flood-control bills of the "omnibus" type. According to the Izaak Walton League of America, several of these bills contain a conglomeration of projects with no valid excuse for execution at this time. One proposes, in effect, to blanket the United States with hydro-power projects and to provide for further multiplication of high dams on important rivers and their tributaries. One bill (H.R. 1823) would establish an Arkansas Valley Authority and another (H.R. 5129) would establish a Columbia River Power Authority. The League maintains that these bills would, in part, sabotage the defense program by diverting funds, man power, and materials from valid defense measures.

Conclusion.—Gradual progress in acceptance by the States of the principles of the *American Fish Policy* has occurred during the year, particularly in the granting of regulatory powers and in the application of natural management measures. On the other hand, it may be noted that other influences are upsetting natural balances and destroying opportunities for the conservation and restoration of our natural biological resources more rapidly than they can be offset by the gradual progress evidenced in various phases of the foregoing report.

REPORT OF THE DIVISION OF ANGLING

JAMES A. RODD

Because so much has been written in regard to all forms of angling and it is so difficult to think of anything to avoid a repetition of the soliloquies and imaginations alcoholic and otherwise, of exponents of the art, when I found that I had been elected Vice-President of the Division of Angling of this Society, I immediately thought of taking refuge under the resolution that is reputed to have been adopted unanimously in 1870 at the organization meeting of the American Fish-Culturists Association (the predecessor of the American Fisheries Society), "that the executives must be composed of the feeble-minded members and consequently they must not prepare or submit a paper or a report." On second thought however, I consulted the *Transactions* of the Society and reports of my predecessors in office with the hope that they might have overlooked some points that I might refer to as there have been no material changes in my time in the gentle art of "fooling the fish" of which so many have written. More and more species are being regarded as game fish and anglers have become more expert and their lures and tackle have become more refined, and, on the whole, more deadly as the years have gone by until angling is frequently referred to by its critics as "murder as a fine art."

Although the Society, under the name of the American Fish-Culturists Association, was organized in 1870, it was not until 40 years later at the annual meeting held in New York City, in September 1910, that the Constitution was amended to provide for Divisions as we now have them, including the Division of Angling, with a Vice-President for each Division. The first Vice-President of the Division of Angling was the late John E. Gunckel of Toledo, Ohio. At the annual meeting the following year held at St. Louis, Missouri, in October 1911, the Secretary reported that Mr. Gunckel would submit a report on angling, but such a report does not appear in the *Transactions* for that year. There was no report on angling for 20 years and I began to think that the principles of the resolution that I referred to earlier had been put into practice by the

nominating committee, and a report on angling was not expected. Unfortunately, my hopes in this regard were blasted by my friend Fred Westerman who submitted the first report of the Division of Angling at the meeting held at Toronto in August 1930. Since 1930, Mr. Westerman's example has been followed each year by his successors with the exception of 1932, 1938, and 1940, when no reports were submitted. I did not feel that I would care to be responsible for breaking further the example so nobly set by Mr. Westerman after so many barren years, particularly as I was at one time an enthusiastic fisherman and have been fortunate in that from time to time my work has taken me to almost every district where the best fishing that Canada has to offer is found. I have come in contact with anglers of many kinds and conditions, from the Indian who fishes for food to the bloated plutocrat with his diversified and sometimes dreadful assortment of lures and tackle, not overlooking the dry-fly purist. These contacts strengthened in my mind the truth of the Hindu proverb, "All men are equal before fishes."

Angling and anglers have been described in many ways. The fishery regulations for the Dominion of Canada define angling as: "The taking of fish with hook and line held in the hand, or with hook, line and rod, the latter held in the hand but shall not include set lines or lines tied to a boat." Angling has also been described as, "A delusion entirely surrounded by liars in old clothes."

There are anglers of many grades and classifications, such as "fans," "fanatics," and "fakirs." The much-quoted Izaak Walton said that anglers are civil, quiet men; followers of peace; patient, cheerful and hopeful. Mr. Walton, however, was prejudiced in his views, as many anglers are anything but quiet when they have imbibed freely of the bait that anglers are reputed to carry, or in any but a cheerful state when they have hoped for the so-called "Fisherman's Paradise," but have found that the mosquitoes, flies, and other insects bite most vigorously but the fish don't. If they are novices they are liable to return home convinced that the particular fish they were after is a species known chiefly by hearsay, or that good fishing is "where you ain't." As opposed to Walton, anglers have been described as, "fat men in wet clothes, rubber boots, and frustrated expressions." A fishing trip, however, with congenial friends, is mentally and physically beneficial to mankind, because:

> "A feller isn't thinkin' mean—out fishin';
> His thoughts are mostly good and clean out fishin';
> He does not knock his fellowmen, or harbor any grudges then;
> A feller's at his finest when—out fishin'.
> A feller's glad to be a friend,—out fishin',
> A helpin' hand he'll always lend—out fishin'.
> The brotherhood of rod and line
> An' sky and stream is always fine,
> Men come real close to God's design—out fishin'.
> A feller isn't plotting schemes,—out fishin'.
> He's only busy with his dreams—out fishin'.
> His livery is a coat of tan; his creed to do the best he can;
> A feller's always mostly man,—out fishin'.
> A feller gets a chance to dream—out fishin'.
> He learns the beauties of a stream—out fishin'.
> And he can wash his soul in air
> That isn't foul with selfish care,
> An' relish plain and simple fare—out fishin'."

An angler's enjoyment is not only in the present but in retrospect as well as in prospect.

The overhaul and care of tackle during the winter months is not without enjoyment and a well-worn fly may bring back many pleasant recollections, as is so aptly expressed in "The Fly Book.":

"Nestled together, rows on rows
With their keen, sharp-pointed toes,
Here a Hare's Ear, there a Glory,
A Royal Coach with a wondrous story.
Wickhams, Fairies, a tiny Dun
That could tell of an hour of glorious fun
As a deep, dark pool, in the shadows dense,
When the heart beat fast and the nerves were tense.
And six bright beauties rose and took
Each in his turn that fateful hook,
And I care not whether they're wet or dry,
Fancy or Somber, yea, not I . . . .
I love them all, yes, every fly."

The question of veracity and alcoholic beverages frequently is associated with anglers and fishing trips, as suggested by the following well-known lines:

"Behold! The Fisherman,
He riseth up early in the morning,
He disturbeth the whole household with the
noise of his preparations,
He returneth in the evening smelling of strong drink
and the truth is not in him."
and
"O, the angler plays for the pleasure of the game
And his creel may be full or light
But the tale that he tells is just the same
When he lies by the fire at night."

Not the least enjoyment of angling is the fish stories that it gives rise to, as for instance the one of the Scottish laird, who in a misguided moment had handed over the charge of the liquid refreshments to his gillie. Intent on his fishing, failed to note Jock's frequent application to the bottle with the consequence that when he was fighting a good fish he warned Jock to be ready with the gaff. Jock who by this time was rather helpless replied: "I canna gaff it, I (hic) can see three fush." "Then for Heaven's sake," urged the laird, "when I bring it into the bank, gaff the middle one." Whereupon Jock made a wild stab, missed the fish, caught the cast, which snapped, and the fish rolled away downstream. Naturally the laird was furious and amongst other things said, "Didn't I tell you to gaff the middle fish?" "Aweel," Jock retorted, with an air of injured innocence, "I did see three fush and I did gaff the middle ane, but (hic) I think I maun hae gaffed it with ane oo the ootside gaffs."

Another angler interested an enormous salmon that he was very ambitious to land. He tried dry flies, wet flies, prawn and, at the suggestion of his gillie, a worm, without result. The guide who was keener than the angler said, "There is just one more possibility—let me set that worm, Sir." So, when he had it, he took out his flask and poured a generous portion of his home brew on the worm. The angler tried another cast and as the worm came round it connected and, after a vigorous struggle the salmon was landed, and in accordance with the usual practice, was duly admired and its weight estimated. When the angler looked to see how the salmon was hooked he exclaimed, "My Heavens, that salmon wasn't hooked, the worm had it by the throat!"

Anyone, who has the desire, should go fishing whenever he can. He should sow his wild oats as an angler in his youthful days and he will be happy in pleasant recollections as he grows older, and when his fishing days are over. One writer advises fishing:

"When troubles seem to overtake,
And friends who once were true forsake,
When fears and doubts each moment shake,
Go Fishing.

Just grab a pole and can of bait,
Go right away—don't hesitate,
To-morrow may be just too late
For Fishing.

If you would laugh; real pleasure gain;
Hear music in a sweet refrain;
If you would be a kid again,
Go Fishing."

A great deal has been written concerning the origin of angling. One student of ancient script maintains that Seth, the son of Adam, taught the art to his sons. Another came to the conclusion that if a log of the Ark were available entries would be found to the effect that Noah's sons spent their off watches angling with feathers from the chicken coop because no other bait was obtainable as there was only one pair of each type creature on board that ship. This second student also concluded that irrespective of who initiated angling, it remained for the Scotch to perfect the salmon fly and salmon-fly fishing and that the clan with the gayest tartan made the gaudiest flies and the wearer of a particularly bright kilt had to sleep in it when near a salmon stream, or he was in danger of waking up minus his national garment.

A report on angling should not conclude without a plea for the wise utilization of our wild life, based on knowledge of its needs, with proper safeguards for the future which is well expressed in the words of Edgar A. Guest:

"For fish and birds I make this plea,
May they be here long after me.
May those who follow hear the call
Of old Bob White in spring and fall;
And may they share the joy that's mine
When there's a trout upon the line.

I found the world a garden spot,
God grant the devastating shot,
And barbed hook shall not destroy
Some future generation's joy.

Fancy a youth with all its dreams,
That finds no fish within the streams.
Our world with life is wondrous fair,
God grant we may not strip it bare!"

REPORTS OF STANDING COMMITTEES

REPORT OF THE COMMITTEE ON INTERNATIONAL RELATIONS

PAUL R. NEEDHAM[1]

The present critical international situation has led to increased fishing effort in non-combatant areas which may seriously deplete fish stocks. In combatant areas, with millions of people in European countries facing starvation, it is evident that once the conflict has ended fishing will also increase. Thus we are entering on a more or less prolonged period of greatly intensified fishing. Even now the increased canning of marine products for human consumption, in addition to reduction to provide oils and meals, is accentuating problems of overexploitation. The National defense situation has increased demand for canned fish by reason of its concentrated food value and relative imperishability, and because canned fishery products are not destroyed easily by bombing from the air. At the same time stoppage of imports of cod-liver oil has increased the demand for other marine oils as a source of vitamin products. The feeding of vitamin products to combatant forces to keep them in top fighting condition has increased the demand for various fish oils enormously. Fisheries of international importance, such as those for the cod, sardines, herring, haddock, and salmon have all been affected and we may look forward to greatly intensified fishing with all its implications and dangers to sound conservation.

Canadian problems.—A pack of approximately 1,700,000 cases of salmon is anticipated in the Dominion of Canada during 1941. The British Government desires about two-thirds, or 1,200,000 cases. The remainder apparently will be sold on the domestic market. This unusual demand has affected certain international regulations and as a result a very stringent check is now maintained on exports of salmon. The only exports permitted to the United States at the present time are spring salmon to be used for mild curing and the fresh-fish market. The species which is used for canning (the coho), or which may be used for canning most economically, is being kept in Canada insofar as possible. This restriction is necessary if the Canadian Government is to fulfill its obligation and process the 1,200,000 cases desired by the British Government.

Late in 1940 regulations were promulgated by Canada relative to the importation of eastern shellfish from the United States. The restrictions imposed amounted, practically, to a total embargo. The object of the restriction was to conserve Canada's foreign exchange. The effect on the Pacific Coast oyster industry of Canada was that it was called upon to supply a large quantity of fresh Pacific oysters to take the place of the eastern oysters on the markets of large cities in eastern Canada. Just how long the supply can be maintained will depend on how long oyster spat can be obtained from Japan. Canadian oystermen on the Pacific Coast secured a sufficient supply of Japanese spat during the past year, but in the immediate future this avenue of purchase may be closed.

Such economic disturbances are inevitable in war time, but National and international conservation agencies must guard against over-exploitation of fishery resources during periods of great emergency unless the stocks are to become seriously depleted and even exterminated beyond power of recovery.

The North American Council on Fishery Investigations, by means of which the United States, Canada, Newfoundland, and France have cooperated in scientific investigations of the North Atlantic fisheries, has held no meetings since 1939. The organization remains active, however, and will resume regular meetings as soon as international conditions permit. The more eastern fishing

[1]Read by Charles E. Jackson, in the absence of Dr. Needham.

grounds for cod, haddock, and mackerel have been fished but lightly during the past year because of the war. These areas might possibly be fished by United States vessels to help produce food for belligerent countries until food supplies can be provided through restoration of fishing activities by the European nations.

Condition of the lobster fishery.—The lobster fishery of the North Atlantic furnishes a large part of the income of small-boat fishermen from New Jersey to Newfoundland. In 1939 the catch was valued at over 5 million dollars, of which about 2 million represented the income of United States fishermen, and 3 million the income of Canada and Newfoundland. Largely because of complications in international trade and because of differences in size limits among the various States and countries concerned in the lobster fishery, the problem has assumed considerable international significance. In order to study methods of conserving and restoring the lobster supply and to improve marketing conditions the North Atlantic Lobster Conference was organized in 1940 by State conservation officials, representatives of the industry, and State and Federal fishery biologists. A research committee was appointed by the Conference and Canadian officials and biologists have collaborated with those from the United States in an endeavor to find solutions for their common problems.

The supply of lobsters has been threatened by the lack of uniform size limits large enough to allow sufficient lobsters to spawn and thus maintain the stocks. The fishermen of States where size limits are in effect suffer through importations from areas where smaller or no size limits are in effect. Stabilization of exports from Canada and Newfoundland, which now are distinctly seasonal, will distribute the peak over a longer period and thus improve market conditions as well as the earnings of individual fishermen.

Great Lakes fisheries.—For many years there has been a more or less continuous and serious decline in the abundance of the valuable food fishes of the Great Lakes. Overfishing has been isolated as one of the principal causes of the decline. These fisheries are administered by eight States and by the Province of Ontario and repeated attempts to bring about uniformity in regulations and methods of administration and enforcement have failed. An International Board of Inquiry for the Great Lakes Fisheries, established on February 29, 1940, by an exchange of notes between the Governments of the United States and of Canada has now held 31 hearings in Great Lakes Cities of the United States and Canada. More than 1,500 commercial fishermen, public officials, and sportsmen attended and gave important testimony. The Board has received enthusiastic response at all of its hearings and obtained splendid cooperation from the conservation officials of all of the various administrative agencies. The Board expects to complete its work and submit a report and recommendations during 1942.

Missisquoi Bay and Lake Champlain.—An International Commission appointed in 1929 to study the pikeperch fishery and international problems associated with the game-fish resources of Lake Champlain and Missisquoi Bay completed its actual investigations during 1931. A preliminary draft of the report is undergoing revision and the final report will be submitted to the two Governments as soon as pressing conditions of the present emergency will permit.

Fishery Mission to Mexico.—Pursuant to requests of the Government of the Republic of Mexico for assistance in developing, conserving, and rehabilitating the fresh-water and marine fishery resources of the country, a preliminary survey was made during the fiscal years 1940 and 1941 through the half-time detail of an aquatic biologist from the United States. On the basis of the preliminary reconnaissance a comprehensive program was formulated. The studies undertaken during the latter part of the fiscal year 1941 by two biologists of the Fish and Wildlife Service of the U. S. Department of the Interior assigned to the work, include: (1) A survey of lakes and streams of the Central Mexican Plateau to determine the nature of the waters, their ability to support fish populations, and to ascertain what species should be introduced or artificially propagated in order to develop

a substantial food-fish and angling resource. (2) A survey of present fish hatcheries and fish-cultural practices to facilitate recommendation and initiation of improved techniques. (3) A determination of the abundance, natural history, and migration of shrimp, commercial fishes, and mollusks in order to develop and recommend measures for the conservation of the resources and improvement of the food supply of the country.

Because of the magnitude of the problems presented and the diversity of waters and forms of aquatic life to be studied, successful completion of the objectives of the mission will require several years of uninterrupted effort.

Transfer of fish eggs to South America.—As a result of appropriations made by Congress for cooperation with American Republics, fish eggs may be provided by the Fish and Wildlife Service of the U. S. Department of the Interior for stocking waters in other American Republics. Two shipments, each of 100,000 rainbow trout eggs, were made to Colombia on January 3, and June 6, 1941, respectively. The eggs are incubated at one of the hatcheries in that country and the resultant fry planted in local waters to improve the angling conditions. Preliminary arrangements have been completed for the shipment of lake trout and whitefish eggs to Peru during the coming fall and early winter for stocking Lake Titicaca.

Fishery Mission to Peru.—The development of new domestic fisheries is particularly important if defense activities are to be accompanied by the provision of ample and additional food supplies. Exploratory work off the coasts of neighboring countries not only results in augmenting the total food supplies of the Americas but improves international relations. During the past year the Fish and Wildlife Service of the U. S. Department of the Interior furnished personnel for a fishery mission to Peru for the purpose of conducting economic, technological, and biological studies of the fisheries of that country. Expenses of the mission were borne by the Peruvian Government. The survey made by the mission revealed the existence of rather extensive fishing areas off the coast of Peru, existing marketing practices have been studied and improvements recommended, and extensive researches have been conducted on the preservation and processing of South American marine fishes. The fishing vessel chartered in the United States by the mission has been purchased by the Peruvian Government in order that it may continue the exploratory and experimental fishing. Machinery for manufacturing fish meal and oil, and fishing gear also is being obtained.

Fraser River sockeye salmon.—This is the fourth year of work by the International Pacific Salmon Fisheries Commission, established by convention between Canada and the United States, on the sockeye salmon problems of the Fraser River. An investigation is to cover a period of 8 years, or 2 cycles of the 4-year life of the sockeye salmon. This is the last year of the first cycle, and next year the incoming adults will be offspring of the first run observed by the Commission.

The investigative program has been directed mainly toward discovering basic facts necessary for proper regulation. A study is being made of the behavior of the adult fish during migration, including the length of their stay in each locality, the time of their passage, and of their upstream migration. About 10,000 fish have been marked each year from which returns have been as high as 60 per cent. The Commission also has inaugurated a careful study of the catches and escapement in order to determine accurately the ratios between the two variables. Since regulatory powers will be assumed by the Commission at the end of the second 4-year cycle, or in 1945, the basic comprehensive investigation now in progress will provide a sound basis for future management.

Pacific halibut.—The halibut fishery of the Pacific Coast, which is regulated and studied by the International Fisheries Commission established by convention between Canada and the United States, has continued to demonstrate improvement. The 1940 season was the shortest in the history of the fishery and the total landings amounted to 53,000,000 pounds, compared with 46,500,000 pounds in 1935.

Fur seals.—Late in 1940 the Japanese Government served notice of her intention to abrogate the Pelagic Sealing Treaty concluded in 1911 by Japan, Russia, Canada and the United States. The abolition of pelagic sealing in 1911 is an outstanding example of good management of an aquatic resource, for the seal herds on the Pribilof Islands have increased from approximately 125,000 animals in 1911 to more than 2,100,000 in 1940. This is probably the first important instance of a backward step in international cooperation to conserve a marine resource and it would be unfortunate if the gains of decades should be wiped out in a few years by a return to the former destructive and uneconomical methods of exploiting the fur seal populations.

Other international problems.—There are many additional international problems caused by overlapping of fishery interests that do not come within the purview of any existing international board or commission. Sport and commercial fishing for a number of species is carried on by California boats off Lower California and in the Gulf of California. The California tuna boats operate in these waters and also off the coasts of Central America and Ecuador. These are mostly fisheries of the high seas and a primary source of complication now arises from the necessity of securing bait and supplies inshore where various fees may be levied and regulations imposed. As far as conservation is concerned the State of California is studying most of these fisheries and has some regulatory powers over California fishermen. Whether this constitutes adequate and effective control over long periods of time remains to be seen. Surely development of fisheries by the nationals of other American Republics off their own coasts is likely to complicate the problem of conservation.

A fishery treaty was concluded by the United States and Mexico in 1925 but lasted only one year because too many controversial matters were included. It is hoped that treaties or future agreements will provide for commissions or boards which can solve some of the international questions much in the same manner as the joint bodies are now operating with reference to United States and Canadian fishery problems.

Specifically, your committee recommends that those members of the American Fisheries Society concerned with the administration of or biological studies of fisheries of international scope and who become aware to critical conditions that may seriously endanger the future of the resources, inform the Society of these conditions so that appropriate action may be recommended to responsible authorities.

REPORT OF THE COMMITTEE ON STATE AND NATIONAL RELATIONS

M. C. James

The report of this committee could be made just as well by members of the Society on the floor as by the chairman. Most of you are connected with some official State or Federal organization and are well aware of the extent to which your State maintains cooperative relations with Federal agencies in the conduct of fishery conservation activities.

As far as the Fish and Wildlife Service of the U. S. Department of the Interior is concerned, you probably are well aware that cooperative integration of many fishery activities is being pushed forward as rapidly as practical difficulties and obstacles can be overcome. It is a settled, established policy of the Service to enlist the aid of the States in handling any fishery problem where the States has a significant interest and is in a position to contribute to the solution of the problem. Lest this statement present too rosy a picture, it should be pointed out that conflicts do develop and State and Federal procedures may clash. Such occurrences may result in failure to meet on a common ground and leave both sides only with some completely new and glowing good intentions.

The actual difficulties present themselves when discussions reach the stage of devising ways and means. Merely as one example of many, the effort to coordinate the distribution of products of State and Federal hatcheries in the State of Missouri may be cited. Two years ago both agencies agreed that an orderly program of utilizing the game fish and panfish produced at their respective hatcheries was in the interest of efficient conduct of the work of both agencies. However, when it came to the point of putting such a policy into effect the divergent policies and practices of fish distribution appeared to present insuperable complications. For example, the Federal agency adheres to a policy of taking care of stocking requirements on Federal lands, such as waters of National forests, even though State hatcheries are so located as to be able to perform this service equally well. This and other conflicts resulted in an adjournment with no real progress made toward budgeting the hatchery output except for an appreciation of the other fellow's problems. Meanwhile, we considered the situation, and when we got together again a satisfactory decision on several points and a workable program bloomed as naturally as the flowers in the spring. The moral of this parable is that both the Missouri Conservation Commission and the Fish and Wildlife Service were actuated by a sincere desire to cooperate, and some degree of coalition was therefore inevitable even though it is still imperfect and will require further polishing and furbishing.

Instances of a similar nature are numerous, and are known to many of you. Rather than take your time with a long recital of specific examples, I take the liberty of referring those bent on further inquiry to the official reports of the State Conservation Departments of the former Commissioner of Fisheries and of the Director of the Fish and Wildlife Service. These reports are concrete evidence that when it comes to boosting the welfare of aquatic resources, the States and Federal Government are able to get together and come out of some smoke-filled room with the sort of an agreement that spells good administration.

The States must at times handle their fishery problems with Federal agencies other than the Fish and Wildlife Service. Naturally, to these other agencies fish are probably a secondary consideration, and consequently the State relationships do not always flow in sweet harmony. I have no intention of elaborating on the instances where Smith of some Federal Department and Jones of some State Department have failed to see eye to eye on some fishery matter, except to point out that as a rule the fireworks are traceable to the functioning of the Federal Government as a landlord. Here, too, you can search your own memories and consciences for the case histories. Somehow, these conflicts also, have a way of ironing themselves out as Time exerts its soothing power.

If the rift persists, however, it is always in order to look for a referee. The Fish and Wildlife Service, as a Federal organization, might be considered as falling short of an ideal of impartiality in any dispute involving the Federal Government and it is well aware of what happens to the innocent bystander when the dead cats start to fly. Nevertheless, controveries involving fish are likely to land in Dr. Gabrielson's all-embracing lap sooner or later, and it would seem preferable to call in the Doctor for consultation before the case gets too serious for homely remedies. This is no suggestion or recommendation, but is merely the reaction of one who has viewed the progress of several controversies which should never have occurred.

A live aspect of this general subject is the question of whether there is need for some formal channel for conducting the State-Federal relations, or whether they should be left for individual handling as specific problems arise. Several years ago an organization, known as the National Planning Council, was set up as an instrumentality for facilitating the development of cooperative relationships. This group functioned for several years, and apparently did not live up to expectations since it has lapsed. Its successor, if any, may be considered to be the yearly discussions between Dr. Gabrielson and staff members, and the State officials, in conjunction with the joint meetings of the American Fisheries Society and the International Association of Game, Fish and Conserva-

tion Commissioners. The major problems can be cleaned up at such meetings, but there remain numerous minor interpretations and reconciliations which require further attention and are the subject of more or less continuous discussion and correspondence throughout the year. The regional organization of the Fish and Wildlife Service greatly facilitates these contacts of the men who have the real responsibility of putting cooperation into effect. The existing situation is in the process of evolution, and very likely represents the most practicable machinery for keeping in step with each other.

Personalities are inevitably a feature of the more or less delicate art of give and take. Frequently, this element may be of greater importance than the cold facts of the case. This is one of the numerous penalties imposed on us for being human, but it need not sway the course of events too much if due respect is given to the other party's motives and the reasons which impel him to adopt his views.

It is further noticeable that once satisfactory working arrangements have been formulated, they remain effective until a change of personnel occurs. More often such changes are within a State organization, and a new regime may feel obligated to start with a clean sheet. This means getting acquainted all over again, and reopening questions and problems which had already been wrapped up and tucked away in mothballs. If the cooperative relationships are reduced to some sort of a formal or semi-formal agreement or memorandum of understanding, they are much more liable to survive changes of administration. On the other hand, it is often difficult to draft agreements that are sufficiently broad to cover the multitude of unforeseen contingencies which may arise in connection with enterprises involving the erratic factors of fishery biology. A certain amount of elasticity is as essential to these relationships as it is to a stream-lined bathing suit. However, the tendency is constantly in the direction of drafting master agreements to agree, and then working out specific undertakings within the framework of the general understanding.

With no Federal aid or Pittman-Robertson set-up for fisheries, we are liable to go on improvising and playing by ear for an indefinite period. However, if the Buck Bill, the fishery version of the Federal Aid in Wildlife Restoration Act can hurdle the obstacles imposed by current National and international conditions, and become law, a new era in Federal-State relations will have dawned. While there is not full agreement as to the desirability of this legislation, I am confident that it will prove itself if it is ever enacted. To me, this is the big objective in cementing the elements of the present loose, but sound structure of State and Federal relations.

It would be an unwarranted intrusion on your time to attempt to comment on all of the phases of this most important element of fishery administration. There is, however, every reason to feel encouraged over the persent status and prospects for gains in the immediate future.

REPORT OF THE COMMITTEE ON COMMON AND SCIENTIFIC NAMES OF NORTH AMERICAN FISHES

WALTER H. CHUTE

The work of the Committee on Common and Scientific Names of Fishes has progressed but slowly during the past year. As reported at the last meeting, the original committee of 7 has been assisted in this work by a group of 19 additional workers distributed throughout the United States and Canada, and many of these workers have consulted others in their respective localities. The principal cause of delay has been the difficulty in securing the return of the marked lists. Of the 26 lists sent out in July 1940, the twenty-fifth was received in February and one list has not been returned as yet. Unfortunately,

some of the gentlemen whose opinions are apt to bear the most weight appear to be the busiest and their lists are often the last ones received.

That some progress has been made is evidenced by the fact that of the approximatly six hundred fishes under consideration, the ratio of names unanimously accepted for the official list has arisen from 50 per cent to 70 per cent. Of the balance, 20 per cent more have received a two-thirds vote, but a "vociferous minority" makes it advisable to re-submit some of these once more. The remaining 10 per cent, or slightly more than 60 names, are still subject to considerable discussion. Some of them have three names proposed, with the vote equal between the three. In many cases the arguments are purely sectional, but others are argued on sentimental or commercial grounds.

The chairman now has under preparation the third revised list. Previous lists were divided into three sections, one each for the Atlantic and Pacific coasts and one for fresh water. The new list, which will contain all of the more than six hundred fishes, will be a combined list for the entire area covered. The fishes will be grouped in natural groups, orders, families, etc., regardless of habitat, so that workers may more readily recognize the natural affiliation of the fishes in their particular field of operations with those in other localities. In this way it is hoped that the incorrect application of some of the common names now in use will be recognized. In addition to the single official names to be decided on, there are an equal number of secondary and local names that are under consideration for inclusion in the alphabetical index which will accompany the completed list.

To prevent what promises to be an endless argument on a few controversial names, it is now planned that after the vote on the next list is received, those names that fail to receive a two-thirds majority will be re-submitted to the seven members of this committee and their decision will have to govern the selections submitted to the Society.

The preparation of a list of this kind involves a great deal of tedious and careful clerical work and consumes a great deal of time, as it must be attended to at intervals between the demands of regular duties. In view of the experience of the last year, the chairman makes no predictions as to the availability of the completed list by the 1942 meeting. He can assure the Society, however, that when the list is finally submitted, it will represent the *well considered* opinion of a majority of the co-operating group, which includes many of the best known biologists in this country and Canada.

REPORT OF THE COMMITTEE ON PUBLICATIONS

H. J. Deason

The custom inaugurated 2 years ago by the former chairman of the Committee on Publications, Dr. John Van Oosten, of presenting an annual report to the membership has proved so helpful that it is being continued this year. Such a report enables the Committee to present for consideration suggestions for improving the quality of our annual publication, which I think we are all agreed, has become one of the outstanding fishery journals in the World.

Despite our efforts to issue Volume 70 within a very few months after the last annual meeting, various circumstances defeated that objective and members did not receive their volumes until 9 months after the meeting. Labor difficulties at the printing establishment contributed in a minor degree to the delay, but the outstanding factors were the unusually large number of manuscripts presented to be considered for publication, the necessity for returning manuscripts to authors for revision—sometimes as many as three times—and excessive correspondence to clear up questionable points and inaccuracies in the manuscripts that were due almost entirely to carelessness and failure to follow the printed in-

structions. Therefore, the facts and circumstances that make an editor's life uncomfortable which Dr. Van Oosten discussed at length in his report 2 years ago, still are applicable; but I am happy to say that the number of authors to whom those comments apply are becoming fewer each year. To those members who conscientiously strive to assist us, the Committee is indeed grateful. However, as long as members who have good material to present are careless in preparing manuscripts, there will be delays. The Committee cannot and does not reject manuscripts on the basis of poor presentation alone. Rejected manuscripts are invariably based upon faulty material, inadequate information, and illogical analysis and interpretation, or deal with subjects foreign to the interests of the membership of the Society. The only sure method of speeding up publication, which the membership as a whole so earnestly desires, is to avoid the necessity for returning manuscripts to authors for revision.

Some authors still consider that the instructions for preparing manuscripts are an unnecessary evil. However, these same instructions were considered so helpful that the editor of the *Transactions of the North American Wildlife Conferences* requested permission to adopt them, and they served as the basis of the mimeographed instructions issued to authors of papers presented at the Memphis meeting last winter. An independent compilation of instructions from the same basic sources we employed, the United States Government Printing Office Style Manual and the University of Chicago Style Manual, made by the Division of Public Relations of the Fish and Wildlife Service and issued to all employees as a guide for preparing manuscripts, has resulted in a set of instructions identical in most respects with those of this Society. During the past year several members of university faculties were so impressed with the potential value of these instructions in assisting students to write good scientific papers that requests for numbers of reprints were received.

In editing the papers for Volume 70, the Committee was very gratified to note that fish-culturists attempted to follow the instructions, usually with remarkable success, and as a result their papers put those of several experienced biologists to shame. These facts illustrate that the instructions are workable and are not difficult to follow. Clean copy reduces the number of printer's errors—the printer is forced to set the volume in a uniform style and it is the duty of each author to assist him. Last but not least, compliance with the instructions assists in preserving the good disposition and eyesight of the persons who must edit your paper.

It has become apparent that unless there is a substantial increase in the membership of the Society, and hence an immediate increase in annual income, the pagination of next year's *Transactions* will have to be reduced at least 20 per cent. Paper costs are mounting rapidly and hence the basic rates for printing are bound to increase unless the Federal Government shows a disposition to freeze paper prices at last winter's level. At the Toronto meeting a total of 72 papers appeared on the program and 20 were either withdrawn by the authors or were refused publication by a majority vote of the Committee. The 52 papers published, together with the business sessions and appendices, resulted in a volume of 528 pages which cost slightly more than two thousand dollars to publish. The cost of Volume 70 was greater than the Society, with its present income, can afford to bear every year. Because of the change in type of program this year and the consequent need for publishing all of the discussion at the various symposia that are scheduled, the total number of independent contributions that can be published will be much smaller than last year. As in the past, however, all assistance possible will be given to fish-culturists and inexperienced investigators in order that their contributions may be published. The days of rewriting papers for trained biologists are at an end!

Three rules have been in operation with respect to the *Transactions* for several years: (1) Only members in good standing may present papers, either by reading or by title, at an annual meeting and publish them in the *Transactions*; except that the President may invite one or more outstanding non-members to present papers and to such persons the rule shall not apply. (2) No member may present

more than two papers at an annual meeting or publish more than two manuscripts in any one volume of the *Transactions*, joint authorships counting the same as sole authorships. (3) Members, on request, may be permitted a period of 30 days after the close of the annual meeting to revise their manuscripts and transmit them to the Committee on Publications. These rules were adopted originally by vote of the Executive Committee and approved by vote of the membership, but only one of these, the provision of an extension of 30 days after the meetings for revising papers, is included in the By-Laws of the Society. Since they provide a just protection and equality of opportunity for members of the Society, the Committee on Publications recommends to the President that he instruct the Committee on Resolutions to draft and submit for the consideration of the membership, the necessary amendment to the subsection of Article II of the By-Laws of the Society, entitled: "Rights and duties of members."

Many members perhaps have noted that Volume 70 of the *Transactions* has been copyrighted in accordance with the laws of the United States. The primary reason for copyrighting is to prevent republication of the same material without an acknowledgment that it was first published in the *Transactions*. The *Transactions* have been discredited on several occasions in the past by such occurrences. It is not intended that the copyright will prevent reprinting of portions of any volume. It merely insures that such republication will contain adequate acknowledgment. The copyright law in no way interferes with quotation of material by authors in writing other papers, and for such minor quotations no acknowledgment, other than the customary standard literature citation, is necessary.

Last fall the Committee on Publications recommended to the Executive Committee that the sale price of the index to the *Transactions* for the years 1872 to 1928 be reduced 50 per cent in order to enable the Society to recover some of its investment on a dead stock of 800 copies. This recommendation was approved and an advertisement of the revised prices appears on the back cover of Volume 70. Those who do not have a copy of the index and who neglected to purchase one because of the former high prices are urged to take advantage of this opportunity. Each volume since 1929 has its own index, but the composite index is the only means of ready access to the wealth of material contained in earlier volumes.

The Committee on Publications respectfully requests, in accordance with the policy established last year, that the Society provide an appropriation of not to exceed $125.00 to cover the costs of proofreading, indexing, clerical services for the chairman, and postage and express charges, incidental to the editing and publication of Volume 71 of the *Transactions* which will contain the proceedings of this meeting.

REPORTS OF SPECIAL COMMITTEES

REPORT OF THE POLLUTION STUDY COMMITTEE

KENNETH A. REID

For several years past the American Fisheries Society has endorsed and supported legislation initiated by the Izaak Walton League of America in the Congress of the United States, to control pollution on a nationwide basis by watersheds. Last year in the interests of at least making a start in preventing the spread of pollution to new industries and unpolluted sources, the National organizations including the American Fisheries Society, supporting the so-called Mundt Bill for actual control of pollution, agreed to drop that bill in return for inclusion of the so-called Mundt Amendment in the Barkley Bill. The Barkley Bill provided no control whatever over pollution by any agency, but provided merely for further study and voluntary action with some financial assistance for polluters who wished to avail themselves of it.

With the inclusion of the Mundt Amendment, the Barkley Bill had some value, for that amendment while not affecting existing pollution, did outlaw the spread of the evil. While this amended bill was far from adequate legislation, it seemed under the circumstances the wisest course to accept such a compromise for the worthless Barkley Bill was on the calendar while the Mundt Bill was still in committee with little likelihood of its being considered or getting out of committee for a vote.

With the support of the National conservation organizations as well as much public support, the Barkley Bill with the Mundt Amendment included, was passed by a record vote in the House, and in July 1940 was reaffirmed by the House by another record vote, when the polluters opposing it attempted to have the amendment stricken out. Unfortunately, Senator Barkley, who has consistently opposed pollution control and cooperated with the U. S. Chamber of Commerce and other similar agencies to that end, was successful in keeping the amended bill in the joint conference until Congress adjourned, when the bill died.

On March 6, 1941, Congressman Mundt introduced the new pollution control bill (H. R. 3778) in the House, and on March 17 Senator Gillette of Iowa, introduced an identical bill (S. 1121) in the Senate. The former was referred to the Rivers and Harbors Committee and the latter to the Commerce Committee, where they both still lie. Advice from friends of clean streams in the Congress is to the effect that Congress is so absorbed with National defense measures, valid and otherwise, that it would be inopportune to press for hearings on these bills until a later date. The Izaak Walton League is keeping in close touch with the situation and will ask for hearings at the first favorable opportunity, and at that time will advise the various national conservation organizations and societies and invite their participation and support.

These current bills represent 5 years of legislative experience reflecting objections and suggestions from previous hearings. The U. S. Public Health Service replaces the Corps of Engineers of the War Department as administrative agency, in accordance with the expressed position of the President—a logical change when the Army is engaged in National defense. Present as well as future pollution is controlled, yet every courtesy including ample extension of time is provided for polluters; and undue encroachment of Federal authority is prevented by provisions granting existing State agencies and commissions formed under interstate compacts the right to control their pollution if they will. Finally, a provision specifically prevents any interference with operation of vital National defense industry; so we can say without fear of contradiction that these bills answer in advance every legitimate objection leveled at previous bills. Indeed it is incon-

ceivable that anyone who sincerely desires correction of pollution should oppose them.[1]

Aside from the legislative front some progress has been made. Through the support of National conservation organizations Congress increased the appropriations of the Fish and Wildlife Service of the Department of the Interior by the sum of $35,000 to provide for an expansion of its pollution investigations during the fiscal year 1942. Investigations of pollution problems presented by National defense industries and by growing military and naval establishments are thus made possible through the increased personnel and two additional laboratory trucks that have been placed in operation. The investigations are under the direction of Dr. M. M. Ellis. In answer to the specific request of the President, the Secretary of War, the Secretary of the Interior, and the Director of the Office of Production Management each have appointed a liaison officer to work together in solving problems of conservation of fish and wildlife in relation to dangers incident to the expending National defense program. Mr. Albert M. Day of the Fish and Wildlife Service has been designated as the liaison officer for the Department of the Interior. Through his relations with similar officers of the War Department and O.P.M., acting upon the results and recommendations of the pollution investigations conducted by Dr. M. M. Ellis, much new pollution has been prevented.

Industrial pollution by and large, however, still remains a great unsolved problem, and we believe will continue as such until Congress passes appropriate control legislation. As Chief Justice Holmes once said, "The only thing that makes taxes bearable in their uniformity", and so we say that the only thing that will make pollution control effective will be its uniformity, and we can only attain uniformity through control on a nationwide basis by Federal authority.

Following is the complete text of H. R. 3778 introduced by Congressman Karl E. Mundt of South Dakota. The text of S. 1121, introduced by Senator Guy M. Gillette of Iowa is identical:

77TH CONGRESS
1ST SESSION

H. R. 3778

IN THE HOUSE OF REPRESENTATIVES

MARCH 4, 1941

Mr. MUNDT introduced the following bill; which was referred to the Committee on Rivers and Harbors

A BILL

To create a Division of Water Pollution Control in the United States Public Health Service, and for other purposes.

Whereas the public health and natural resources from the first line of national defense; and

Whereas clean water is vital to the public health, to navigation, and to support of invaluable aquatic life and healthful recreation: Therefore

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

[1]Two pollution bills, in addition to H.R. 3778 and S. 1121, were introduced at the first session of the Seventy-seventh Congress: H.R. 1110 was introduced on January 3, 1941, by Congressman Brent Spence of Kentucky and referred to the Committee on Rivers and Harbors. H.R. 4106 was introduced on March 20, 1941, by Congressman Samuel A. Weiss of Pennsylvania and referred to the Committee on Rivers and Harbors. These bills (H.R. 1110 and H.R. 4106) are considered inferior to H.R. 3778 and S. 1121 discussed in Mr. Reid's report.—EDITOR.

That there is hereby established in the United States Public Health Service a Division of Water Pollution Control (hereinafter referred to as the Division). The Division shall be in charge of a Director, who shall be a commissioned engineer

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officer of the United States Public Health Service detailed for such duty by the Surgeon General of the Public Health Service (hereinafter referred to as the Surgeon General). Such engineer officer, while serving as Director, shall have the rank of an Assistant Surgeon General of the Public Health Service, subject to the provisions of law applicable to Assistant Surgeons General in charge of administrative divisions in the District of Columbia of the Public Health Service.

SEC. 2. (a) The Division shall, after careful investigation, and in cooperation with the Chief of Engineers of the War Department, the Chief of the United States Fish and Wildlife Service, other Federal agencies, and the agencies of the several States authorized by law or duly designated to deal with water pollution, and in cooperation with the municipalities and industries involved, prepare comprehensive plans for eliminating or reducing the pollution and improving the sanitary condition of the navigable waters of the United States and tributary streams from which the pollution discharged therein may flow or be carried into the navigable waters of the United States. In the development of such comprehensive plans due regard shall be given to the improvements which are necessary to conserve such waters and promote their use for public water supplies, propagation of fish and aquatic life, recreational purposes, agricultural, in-

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dustrial, and other legitimate uses, and for this purpose the Division is authorized to make joint investigations with the aforesaid agencies of the Federal Government and any State or States of the condition of any waters of the United States, either navigable or otherwise, and of the discharges of any sewage, industrial wastes, or substance which may deleteriously affect such waters.

(b) The Division shall encourage cooperative activities by the several States for the prevention and abatement of water pollution; encourage the enactment of uniform State laws relating to water pollution; encourage compacts between the several States for the prevention and abatement of water pollution; collect and disseminate information; make available to State agencies, municipalities, industries, and individuals the results of such surveys, studies, investigations, and experiments conducted by the Division and by other agencies, public and private; and furnish such assistance to State agencies as may be authorized by law.

(c) The consent of Congress is hereby given to two or more States to enter into agreements or compacts, not in conflict with any law of the United States, for cooperative effort and mutual assistance for the prevention and abatement of water pollution and the enforcement of their respective laws relating thereto, and to establish such agencies, joint or otherwise, as they may deem desirable for making effective such

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agreements and compacts: *Provided, however,* That any such compact or agreement shall not be binding or obligatory upon the signatory States unless it has been approved by the legislature of such States, and by the Congress of the United States, subsequent to the approval of the various State legislatures.

SEC. 3. The Division, upon request of any State health authority and subject to the approval of the Surgeon General, shall conduct investigations and make surveys of any specific problem of water pollution confronting any State, drainage-basin authority, community, or municipality with a view to effecting a solution of such problem, and shall make definite recommendations for the correction and elimination of the deleterious conditions found to exist.

SEC. 4. The Public Health Service shall prepare and publish, from time to time, reports of such surveys, studies, investigations, and experiments as shall be made under the authority of this Act, together with appropriate recommendations with regard to the control of pollution of the waters of the United States.

ESTABLISHMENT OF SANITARY WATER DISTRICTS

SEC. 5. (a) The Division shall classify the navigable waters of the continental United States into districts to be known as sanitary water districts. The Division shall fix and define the boundaries of each such district and may from time to time alter such boundaries. The areas of such dis-

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tricts shall, insofar as practicable, conform to the areas of watersheds not wholly contained within the boundaries of one State.

(b) The Division shall fix standards of purity in each such district for the navigable waters thereof, shall establish minimum requirements as to the treatment of polluting material before it is discharged into such waters, and shall promulgate regulations governing the discharge of any matter or materials directly or indirectly into such waters.

(c) Where compliance with standards of purity fixed by the Division be impossible or impracticable before two years from date of enactment of this Act because no adequate method of disposal or treatment of polluting material is presently known, the Division may grant an extension of time, not exceeding five years from such effective date, to permit such industry to perfect and provide adequate means of disposal or treatment of such polluting material. The burden of proving necessity for such extension shall be upon the industry seeking it, and no extension shall be granted except after public hearing and a finding by the Division of necessity.

If at the conclusion of such extension an effective method of treatment has not yet been developed and the industry can show to the satisfaction of the Division at a public hearing, as above provided, that it has diligently tried to

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develop such method, the Division may grant such further extension of time as may reasonably be necessary.

(d) Where compliance by municipalities or other public bodies with standards of purity fixed by the Division be impossible or impracticable before two years from date of enactment of this Act, because of financial condition or statutory limitations on its borrowing power, the Division may grant an extension of time, not exceeding five years from such effective date, to permit such municipality to make the necessary financial arrangements. The burden of proving necessity for such extension shall be upon the municipality seeking it, and no extension shall be granted except after public hearing and a finding by the Division of necessity.

If at the conclusion of such extension proper financial arrangements have not yet been completed and the municipality can show to the satisfaction of the Division at a public hearing as above provided that it has diligently tried to arrange the necessary finances and has not in the meantime expended or contracted to expend funds for other less essential public works, the Division may grant such further extension of time as may reasonably be necessary.

DISTRICT BOARDS

SEC. 6. (a) In each sanitary water district there shall be a district board. The number of members of each such

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board and the method of selection or appointment and terms of office shall be fixed by the Division in its discretion, except that there shall be at least one representative each from State health departments or other State agencies charged with control of pollution, State fish and game agencies, State departments of agriculture, and State departments of labor embraced within the district, and one representative of industry and one representative of municipalities on the board: *Provided*, That all members of the district board shall be bona fide residents of the district. Each district board shall have not less than seven nor more than twenty-one members: *Provided further*, That wherever any two or more States have heretofore or may hereafter enter into any compact for the prevention or abatement of stream pollution and have provided an agency to enforce the provisions of the compact, said agency shall be designated the district board of that particular watershed.

(b) It shall be the duty of each district board—

(1) to prevent the pollution of waters within the district by voluntary methods insofar as practicable;

(2) to investigate the desirability of making loans or grants in such districts for the construction of public sewage-disposal plants and to investigate the desirability of making loans for constructing private works for the

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treatment of trade wastes and to suggest to the Division the recommending of such loans or grants; and

(3) to institute proceedings for the prevention and abatement of water pollution in such districts: *Provided*, That where a duly constituted State agency or interstate compact with authority to enforce the provisions of this Act is in existence that action by the district board will

be taken only after such existing authorities have been given an opportunity to act, and six months after receipt of written notice from the Division have failed to do so.

SEC. 7. Every loan or purchase of securities by Reconstruction Finance Corporation to finance the construction of treatment works shall hereafter be made only upon the recommendation of the State health authority having jurisdiction and upon the recommendation of the Surgeon General and his certification that such construction is necessary to prevent the discharge of untreated or inadequately treated sewage or other waste which would substantially impair the quality of any waters of the United States.

SEC. 8. (a) There is hereby established in the Division, by detail from time to time, a board of five, three of whom shall be commissioned engineer officers of the Public Health Service, a majority of whom shall be experienced in sanitary engineering, the fourth, the Chief of Engineers, United

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States Army, or a member of the Corps of Engineers designated by him, and the fifth, the Chief of the United States Fish and Wildlife Service or a member of the Service designated by him, all said members to serve without additional compensation. The duties of said board shall be fixed by the Surgeon General, and to it shall be referred for consideration and recommendations, in addition to any other duties assigned, so far as in the opinion of the Surgeon General may be necessary, all reports of examinations, investigations, plans, studies, and surveys made pursuant to the provisions of this Act or hereafter provided for by the Congress. To said board shall also be referred all applications for loans for the construction of necessary treatment works proposed to be made pursuant to section 7 of this Act, and all other matters in connection therewith, upon which report is desired by the Surgeon General, including recommendations as to the desirability of commencing, continuing, or extending any and all projects for treatment works upon which reports are desired and for which loan applications have been made. In the consideration of such proposed treatment works and projects the board shall have in view the benefits to be derived by the construction thereof in accomplishing the purpose of this Act, and the relation of the ultimate cost of construction and maintenance, to the public interests involved, the public necessity for such works and the adequacy

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of the provisions made or agreed upon by the applicant for the loan for assuring proper and efficient operation and maintenance of the works after completion of the construction thereof. The Board shall, when it considers the same necessary, and with the approval and under orders from the Surgeon General, make as a board or through its members, personal examinations of localities where the proposed treatment works are to be located. All plans, cost estimates, information, and arguments which are presented to the board for its consideration in connection with any matter referred to it by the Surgeon General shall be reduced to and sub-

mitted in writing, and shall be made a part of the records of the Office of the Surgeon General.

(b) All special reports ordered by the Congress pursuant to the provisions of this Act shall, at the discretion of the Surgeon General, be reviewed in like manner by the said board; and the said board shall also, on request by resolution of the Committee on Commerce of the Senate or the Committee on Rivers and Harbors of the House of Representatives submitted to the Surgeon General, examine and review the report of any examination, investigation, survey, or project for the elimination or reduction of water pollution or for the construction of treatment works made pursuant to any Act or resolution of the Congress, and shall report through the Surgeon General, who shall submit his

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conclusions thereon through the Federal Security Administrator and the President as in other cases.

SEC. 9. There is hereby authorized to be appropriated for each fiscal year, beginning with the fiscal year ending June 30, 1941, the sum of $250,000 for all necessary expenses of the Division in administering the provisions of this Act, including: (a) Expenses of investigations made under this Act, including (1) printing and binding of the findings of such investigations; (2) the pay and allowances, travel expenses of personnel of the Public Health Service (including commissioned officers) while engaged in field investigation; (3) (upon the approval of the Surgeon General) the expenses of packing, crating, drayage, and transportation of the personal effects of such personnel and personnel of other Government departments on duty with the Public Health Service upon permanent change of station under competent orders in connection therewith while engaged in such investigations; and (4) purchases required for such investigations, without regard to the provisions of section 3709 of the Revised Statutes (U. S. C., 1934 edition, title 41, sec. 5), when the aggregate amount involved does not exceed $100; (b) upon approval of the Surgeon General the necessary expenses of the board of engineer officers providd for in section 8 (a) of this Act.

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INJUNCTION PROCEEDINGS FOR ABATEMENT OF POLLUTION

SEC. 10. Pursuant to the powers of the United States to regulate interstate commerce and navigation; to extend, change, and amend the admiralty and maritime law; to give due effect to the migratory bird treaties; and to protect the fisheries, particularly the anadromous fish, Congress hereby declares the discharge or deposit, directly or indirectly, of any waste, except the normal discharge of sewage from toilets of boats, or from the galley sink drains, or the normal amount of oil that may be discharged from the exhaust pipe of a motorboat, or other substance, whether in a solid, gaseous, or liquid state, into any of the navigable waters of the United States in violation of regulations promulgated by the Surgeon General if such waste or other substance is or may be injurious to human health or to any form of life, including aquatic life, or to migratory birds as defined in the Migratory Bird Treaties

of August 16, 1916, and of March 15, 1937, or impairs in any manner the utility of such waters for navigation purposes, to be against the public policy of the United States and to be a public and common nuisance. An action to prevent or abate any such nuisance shall be brought in the name of the United States by any United States attorney when requested to do so by the Surgeon General or the district board of a sanitary water district: *Provided*, That when a duly constituted State agency or interstate compact with authority to

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enforce the provisions of this Act is in existence, action by the Federal authority will be taken only after such existing authorities have been given an opportunity to act and, six months after receipt of written notice from the Division, have failed to do so. Such action shall be brought as an action in equity and may be brought in any court of the United States having jurisdiction to hear and determine equity cases.

SEC. 11. None of the provisions of this Act applying to industrial pollution shall be applicable during the present emergency when the Secretary of War or the Secretary of the Navy shall have certified that speedy and uninterrupted production by such industry or industries is vital to America's national-defense program and that the enforcement of such provision or provisions would be incompatible with expeditious progress of the national-defense program.

SEC. 12. When used in this Act, the term "State health authority" means the official State health department, State board of health, or such other official State or interstate agency as is empowered with the duties of enforcing State laws pertaining to public health or to the abatement of pollution of waters; the term "treatment works" means the various devices used in the treatment of sewage or industrial waste, including the necessary intercepting sewers, outfall sewers, pumping, and power equipment and their appurtenances; the term "person" means an individual in the

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capacity of proprietor of an industrial enterprise, a partnership, a private corporation, an association, a joint-stock company, a trust, or an estate.

MISCELLANEOUS

SEC. 13. Nothing contained in this Act shall be construed to limit in any manner the rights of any person or public body to bring actions for damage on account of the pollution of any waters or for the abatement of such pollution.

SEC. 14. If any provision of this Act, or the application thereof to any person or circumstance, is held invalid, the remainder of the Act, and the application of such provision to other persons or circumstances, shall not be affected thereby.

SEC. 15. All provisions of this Act applicable to the States shall also be applicable to the District of Columbia and the Territories, including Puerto Rico and the Virgin Islands.

SEC. 16. This Act may be cited as the Water Pollution Control Act.

THE PRESIDENT: The Pollution Study Committee is a special committee appointed at each annual meeting of the American Fisheries Society. I will entertain a motion from the floor for the continuance of this committee if that is desired.

MR. GORDON (Pennsylvania): I move that the committee be continued and that the incoming President be authorized to make such changes in the committee membership as may be considered desirable.

(The motion was seconded and adopted unanimously.)

APPOINTMENT ON COMMITTEES

Auditing Committee

Charles O. Hayford, *Chairman*, New Jersey
Kenneth E. Cobb, Connecticut
Stillman Wright, Utah

Committee on Resolutions

John Van Oosten, *Chairman*, Michigan
Lyle M. Thorpe, Connecticut
Carl L. Hubbs, Michigan
Herbert E. Warfel, New Hampshire
Thomas H. Langlois, Ohio

Committee on Nominations

Elmer Higgins, *Chairman*, Washington, D. C.
James A. Rodd, Ontario
F. A. Westerman, Michigan
C. N. Feast, Colorado
D. N. Graves, Arkansas

Committee on Time and Place

William J. Tucker, *Chairman*, Texas
John Gottschalk, Indiana
George W. Davis, Vermont
Fred A. Thompson, New Mexico
Arthur L. Clark, Missouri

Committee on Pollution Study

Following the close of the annual meeting, and in accordance with a motion adopted by the Society, President-elect Van Oosten appointed the following persons to serve on the special Committee on Pollution Study:

Kenneth A. Reid, *Chairman*, Illinois
Carl D. Shoemaker, *Secretary*, Washington, D. C.
Francis P. Griffiths, Oregon
Seth Gordon, Pennsylvania
A. S. Hazzard, Michigan
S. B. Locke, Massachusetts
Emmeline Moore, New York
James A. Rodd, Ontario
M. W. Smith, New Brunswick

Committee on Publications

Following the annual meeting, and in accordance with the by-laws of the Society, President-elect Van Oosten appointed Dr. C. McC. Mottley, Ithaca, New York, to the Committee on Publications for a term of 5 years to succeed Dr. Paul R. Need-

ham, Stanford University, California, whose term had expired. Dr. H. J. Deason, Washington, D. C., was reappointed to the chairmanship. The membership of the Committee is as follows:

	Term expires[1]
Dr. C. McC. Mottley, Ithaca, N. Y.	1946
Dr. Justin W. Leonard, Lewiston, Mich.	1945
Dr. H. J. Deason, Washington, D. C. *Chairman*	1944
Dr. Ralph Hile, Ann Arbor, Mich.	1943
Dr. Lauren R. Donaldson, Seattle, Wash.	1942

REPORTS OF COMMITTEES

AUDITING COMMITTEE

MR. C. O. HAYFORD (New Jersey): Mr. President, the Auditing Committee has checked the books of the Society, also the supporting vouchers, for the period July 1, 1940, to June 30, 1941, and has found that the report of the Treasurer as submitted is correct.

The Committee recommends the following appropriations for the fiscal year 1941-1942:

For clerical and services for the Secretary-Treasurer, exclusive of expenses incident to the editing, proof-reading and indexing of the *Transactions* of this meeting, an increase of $100 over previous appropriations, or not to exceed a total of $450.

To the Committee on Publications, payable to the chairman in a lump sum on proper voucher to cover the cost of proof-reading, indexing, clerical assistances, and incidental expense, in connection with publishing the 1941 volume of the *Transactions*, not to exceed $125.

From the permanent fund, not exceeding $250 to be added to the appropriation of $250 approved at the 1940 meeting not expended, or a total sum of not to exceed $500 for the use of the Committee on Publications for the purpose of duplicating missing volumes for the permanent library of the Society, and to cover costs of binding two copies of each volume for the permanent library; disbursements to be made upon presentation of proper vouchers.

I move that the report of the Auditing Committee be adopted.

(The motion was seconded and the report and recommendations adopted.)

COMMITTEE ON RESOLUTIONS

DR. JOHN VAN OOSTEN (Michigan): Your Committee on Resolutions submits the following resolutions for the consideration of the Society:

1. Amendment to the By-Laws

WHEREAS, The *Transactions of the American Fisheries Society* are published as a record of the business sessions and proceedings of the annual meetings of the Society, and members of the Society should be afforded equal opportunity for the presentation and publication of original contributions in those fields of knowledge within the range of interests of the Society;

BE IT THEREFORE RESOLVED, That the subsection of Article II of the By-Laws of the American Fisheries Society, entitled, "Rights and Duties of Members," be amended by addition of the following:

[1]Indicates the annual meeting at which the term of each member of the Committee will expire.

To insure equal opportunities for members who desire to list original contribution on the program of the annual meetings and submit them for publication in the *Transactions*, the following regulations shall be observed: (1) Only members in good standing may present papers either by reading or by title at the annual meetings and publish them in the *Transactions;* except that outstanding non-members invited by the President of the Society to participate in the program shall be exempted from this requirement. (2) No member may have listed on the program of an annual meeting, or present, or have published in any one volume of the *Transactions* more than two papers; and for purposes of this rule joint authorships shall compare equally with sole authorships.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

2. High Dams

WHEREAS, The serious impairment or destruction of aquatic resources by high dams in which true public values were not given consideration is a matter of plain record; and

WHEREAS, Interested persons, under such subterfuges as "National defense," "flood control," and other labels designed to mislead the public, have adopted this same program of exploitation of water under the erroneous designation of "public water conservation" on a greatly increased scale; and

WHEREAS, These immense projects, present and planned for the future wholly ignore the biology of water, existing aquatic biological resources, and the public's right to enjoy them; and there are present threats to blanket the country with high dams;

THEREFORE BE IT RESOLVED, That the American Fisheries Society, in convention assembled at St. Louis, Missouri, this twenty-sixth day of August, 1941, oppose the authorization or construction of any more high dams regardless of their stated purpose until such time as biologists have an adequate role in the preliminary planning of all such projects and their reports are made an integral part of the factual data submitted as justification, so that all values from the standpoint of broad public interest may be given due consideration; and unless the new values to be created clearly can be demonstrated to exceed the existing public values displaced, that construction of no dam be authorized; and

BE IT FURTHER RESOLVED, That wherever the necessity therefor is indicated, the installation and maintenance of suitable screens, fishways, or other fish-management devices, be made an integral part of the authorization and that this provision constitute a definite responsibility of the agencies or agency constructing, maintaining and operating the dam; and

BE IT FURTHER RESOLVED that copies of this resolution be sent to the following: The Bureau of Reclamation and the Fish and Wildlife Service of the U. S. Department of the Interior, the Federal Power Commission, the Chief of Engineers of the U. S. Army, and the Appropriations Committee of the House of Representatives.

MR. E. L. LECOMPTE (Maryland): I do not see the necessity of sending copies of the resolution to these Government agencies because the Government would certainly furnish the men to make the biological survey.

PRESIDENT BROWN: The agency who is to construct the dam might not be qualified to make the investigation and would not call in representatives of the proper agency.

DR. H. J. DEASON (District of Columbia): I believe that an investigation is insured under the provisions of the Act of March 10, 1934 (48 Stat. 401): "When ever any dam is authorized to be constructed, either by the Federal Government itself or by any private agency under Government permit, the Bureau of Fisheries shall be consulted, and before such construction is begun or permit granted, when deemed necessary, due and adequate provision, if economically practicable, shall be made for the migration of fish life from the upper to the lower and from the lower to the upper waters of said dam by means of fish lifts, ladders, or other devices."

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

3. Dams on Important Fishing Streams

WHEREAS, No pressing need has been demonstrated for the large flood-control dams proposed for the Willamette River and its tributaries, and since the problem may well be solved more satisfactorily and economically by the construction of revetments at a fraction of the cost of the proposed dams; and

WHEREAS, The proposed high dams for the Santiam, McKenzie, and upper Willamette Rivers would block the runs of salmon and other anadromous fishes and may result in their ultimate extermination in these streams since the Willamette River is the only large tributary below present dams on the Columbia River and therefore is vital to the maintenance of the highly valuable salmon runs;

THEREFORE BE IT RESOLVED, That the American Fisheries Society, in convention assembled at St. Louis, Missouri, on August 26, 1941, oppose as an instrument for the needless destruction of valuable natural resources the proposed dams to be constructed in the Willamette River System; and

BE IT FURTHER RESOLVED, That the American Fisheries Society opposes in principle other proposed dams on important fishing streams until the economic and recreational aspects of the fishery resources have been adequately evaluated and provided for.

(Upon motion, duly seconded, the resolution was adopted unanimously.)

4. Water Pollution

WHEREAS, Water pollution has long been a National disgrace and a most serious limiting factory in fishery production, as well as a menace to health and to National safety, and

WHEREAS, The record of 50 years of effort to correct this evil by means of State or local control indicates conclusively that such means are ineffective, particularly with regard to industrial pollution, because of the reluctance of State or local political bodies to enact and enforce legal restrictions on their industries where competitors in adjacent States are not required to do likwise;

THEREFORE BE IT RESOLVED, That the American Fisheries Society in convention assembled at St. Louis, Missouri, August 26, 1941, affirm its previous position and urge the Congress of the United States to enact uniform Federal legislation that will immediately stop the spread of pollution from new sources and provide positive means for abating and controlling that which now exists in a fair and equitable manner as provided for in H. R. 3778 by Congressman Mundt, now before the Rivers and Harbors Committee of the House of Representatives, and S. 1121 by Senator Gillette, now before the Commerce Committee of the United States Senate.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

5. Federal Aid in Fish Restoration

WHEREAS, The Federal Aid in Wildlife Restoration Act, commonly known as the Pittman-Robertson Act, has been accepted generally as a wise measure for the conservation of mammals and birds; and

WHEREAS, A similar Act to aid in the restoration and preservation of fish would be of vast benefit to all of the people of the United States;

NOW BE IT THEREFORE RESOLVED, That the American Fisheries Society in convention assembled at St. Louis, Missouri, August 26, 1941, reaffirm its previous stand and urge the Congress of the United States to enact, at an appropriate time, legislation similar to that provided for in the Pittman-Robertson Act in order to provide aid in the conservation of our fishes;

AND, That the Secretary of the Society be instructed to send a copy of this resolution to Chairman S. O. Bland of the Committee on Merchant Marine and Fisheries of the House of Representatives, to Congressman Buck and to Senator Clark.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

6. Tribute to Deceased Members

WHEREAS, The American Fisheries Society has suffered a serious loss through the death of the following members:

M. J. Bottinelli, Kellogg, Idaho
Merrill W. Brown, Sacramento, California
Robert E. Ellsworth, Alpena, Michigan
George Gibbs, New York, New York
M. L. Hutton, Ames, Iowa
Gardner Poole, Boston, Massachusetts
George T. Slade, New York, New York
James H. Vogt, San Francisco, California
Dennis Winn, Nashua, New Hampshire

BE IT RESOLVED, That the Society, assembled in convention at St. Louis, Missouri, this twenty-sixth day of August, 1941, express its deepest sympathy to the bereaved families and friends of the deceased;

AND BE IT FURTHER RESOLVED, That the Society acknowledge the contributions to fishery conservation made by these members, which will stand as permanent monuments to their memory.

(Upon motion, duly seconded, the resolution was adopted by a unanimous silent rising vote.)

7. Appreciation of Courtesies

WHEREAS, The American Fisheries Society has been entertained graciously at its seventy-first annual meeting at St. Louis, Missouri, and every courtesy and consideration possible has been extended to its members and guests;

THEREFORE BE IT RESOLVED, That the Society expresses its appreciation and sincere gratitude to the Missouri Conservation Commission, particularly to the chairman, Mr. E. S. Stephens; the director, Mr. I. T. Bode and the members of his staff; to the City of St. Louis, the St. Louis Convention Bureau, the St. Louis Entertainment Committee, the St. Louis chapter of the State Wildlife Federation, to Mr. August A. Busch, Jr., and to the Hotel Statler.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

COMMITTEE ON NOMINATIONS

MR. ELMER HIGGINS (District of Columbia): Mr. President, your Committee on Nominations has given serious consideration to the selection of officers and committee members for the ensuing year. Since at least two of the members of our committee have a record of membership in the Society extending over a period of 20 years, they have been of great assistance in enabling us to follow long-standing traditions, first that the offices and committee memberships be distributed geographically and profesisonally, and second, and equally important, that those of ability, energy and experience be selected. Your Committee on Nominations proposes the following officers to serve during the ensuing year:

Officers

President, John Van Oosten, Michigan
First Vice-President, Joe Hogan, Arkansas
Second Vice-President, H. H. MacKay, Ontario
Secretary-Treasurer, R. P. Hunter, Connecticut
Librarian, Kenneth E. Cobb, Connecticut

Vice-Presidents of Divisions

Fish Culture, James R. Simon, Wyoming
Aquatic Biology and Physics, R. W. Eschmeyer, Tennessee
Commercial Fishing, W. L. Schofield, California

Protection and Legislation, William C. Adams, New York
Angling, Carl D. Shoemaker, District of Columbia

Committee on International Relations

William C. Herrington, Massachusetts, *Chairman*
A. G. Huntsman, Ontario
Charles E. Jackson, District of Columbia
A. L. Pritchard, British Columbia
F. A. Westerman, Michigan
William J. Tucker, Texas
E. L. Wickliff, Ohio

Committee on State and National Relations

Arthur L. Clark, Missouri, *Chairman*
Frank B. Wire, Oregon
C. N. Feast, Colorado
John Gottschalk, Indiana
Fred J. McCormac, Louisiana

Committee on Common and Scientific Names of Fishes

Walter H. Chute, Illinois, *Chairman*
W. A. Clemens, British Columbia
John R. Dymond, Ontario
Samuel F. Hildebrand, District of Columbia
Carl L. Hubbs, Michigan
George S. Myers, California
Leonard P. Schultz, District of Columbia

I move the adoption of the report and the election of the officers and committee members named.

(The motion was seconded, voted upon, and the officers named were declared elected.)

COMMITTEE ON TIME AND PLACE

The Joint Committee of the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners who had been chosen to determine the time and place for the 1942 convention met on the afternoon of August 27. William J. Tucker served as chairman and Lester Bagley as secretary.

After some discussion relative to having a definite date each year for the holding for this joint convention, it was moved by T. H. Langlois of Ohio that the joint meeting of the American Fisheries Society and the International Association of Game, Fish, and Conservation Commissioners be held on the second Monday in September of each year. Seconded by Fred A. Thompson of New Mexico, voted and carried.

Dr. Langlois then moved that the next meeting of the American Fisheries Society and the International Association be held next year during the week beginning September 7, 1942. Seconded by D. J. Taylor of Toronto, voted and carried.

Invitations from the various cities who wish to entertain the convention next year were next considered. Representatives from Baltimore, Pittsburgh and New Orleans appeared in person requesting that the next year's convention be brought to their city. Invitations were also received by letter from:

Colorado Springs, Colo.
Baltimore, Md.
Nashville, Tenn.
Montreal, Que.
Providence, R. I.
Los Angeles, Calif.
Chicago, Ill.
Houston, Texas
Baton Rouge, La.
Cincinnati, Ohio

Columbus, Ohio	Manila, P. I.
Atlantic City, N. J.	Denver, Colo.
New York, N. Y.	Mackinac Island, Mich.
Pittsburgh, Pa.	New Orleans, La.
Niagara Falls, N. Y.	Jacksonville, Fla.
Virginia Beach, Va.	Juneau, Alaska

Dallas, Texas

After due deliberation, it was moved by Mr. Taylor and seconded by P. J. Hoffmaster of Michigan that the next convention of the American Fisheries Society and the International Association of Game, Fish, and Conservation Commissioners be held at New Orleans, Louisiana, beginning September 14, 1942. The meetings of the International Association will be scheduled for September 14 and 15, and those of the American Fisheries Society for September 16-18.

CLOSING SESSION

RETIRING PRESIDENT BROWN: I request Mr. Davis of Vermont and Mr. Tucker of Texas to escort the newly-elected president, Dr. John Van Oosten of Michigan, to the chair.

(Dr. Van Ooosten was escorted to the rostum and applauded by the membership.)

PRESIDENT-ELECT VAN OOSTEN: I am deeply moved by the honor you have conferred in electing me to the presidency of this Society. I thank you very sincerely, and wish to express my appreciation of the fact that the Committee on Nominations has selected for me an excellent corps of assistants. It is my hope that together we may be able to maintain the high standard of service rendered during the past year by the retiring officers. At the end of my year of office I hope to be able to repeat the well-known inscription from a tombstone of a departed member, which read: "I have tried my damndest; Angels could do no more!"

Is there any further business to come before the Society prior to adjournment?

MR. C. O. HAYFORD (New Jersey): The program of panel discussions at the meetings this year has appealed to me very much. Would it not be proper for the Society to consider the question as to whether next year's meeting will consist entirely of discussions, or of a combination program of discussion sections and formal papers.

PRESIDENT-ELECT VAN OOSTEN: That is a good suggestion, Mr. Hayford. It will help us considerably if we have an expression now from the membership as to whether we should continue with the discussion type of program, return to the formal paper type, or have a combination program at the next meeting.

MR. SETH GORDON (Pennsylvania): I am enthusiastic over the results of the panel discussions this year. I am inclined to believe that if we are to get the most benefit from a program of formal papers, only those should be selected for presentation that are of interest to the majority of persons in attendance at the meetings. There are papers dealing with research topics that do not interest everyone but which should be printed as scientific information in the *Transactions*. If a session is arranged for the reading of selected scientific papers and one for panel discussions I believe that both the scientific workers and the fish-culturists and administrators will be satisfied.

PRESIDENT-ELECT VAN OOSTEN: You have made an excellent suggestion. Could not the selection of papers and arrangement of program be handled by the program committee?

DR. H. J. DEASON (District of Columbia): In the past, the program committee has not been appointed until the day before the meetings. On such short notice the program committee is not able to do effective work or to select a good program. Members are required to submit papers at least 2 weeks prior to the meetings. I think that it would make possible a much better program if the President

appointed a program committee at least 2 weeks prior to the meeting and provided them with abstracts of papers submitted so that careful selection could be made of papers to be read at the sessions.

MR. GORDON: If the program committee selected papers for presentation in advance, it would be possible to indicate such papers on the program. It does require time for a program committee to function effectively, and the suggestion of Dr. Deason is good.

DR. R. W. ESCHMEYER (Tennessee): May I offer an alternative to the suggestion made by Mr. Gordon? At least every other year the meetings should be devoted to the presentation of formal papers. Some people are able to attend these meetings only because they are presenting a paper. This point should not be overlooked.

MR. GORDON: What you say is true, but it may happen that when papers are listed on the program, some persons who are scheduled to read papers cannot attend the meeting for reasons beyond their control, and members present would like to hear some other paper read. If you attend a meeting upon the theory that you have a paper listed on the program and may be called upon to discuss and defend your conclusions, you will have ample justification for requesting permission to attend the meetings. I would like to see all papers listed on the program and the papers of the greatest importance and general interest selected to be read first. Those who may not be selected to present their papers, may have an opportunity to do so if time permits and if the members request that the papers be read. It should be remembered that the members might not agree entirely with the selections made by the program committee and that requests for certain papers may be received from the floor.

PRESIDENT-ELECT VAN OOSTEN: Are there any further comments? If not, I should like to have an expression of opinion as to whether you desire a mixed program of panel discussions and formal papers, a program entirely of formal papers, or a program entirely of discussions. I will ask for a show of hands on the mixed program. (Affirmative, 19.) On the program of formal papers? (No affirmative votes.) On the program of discussions only? (No affirmative votes.)

MR. WILL TUCKER (Texas): Mr. President, I believe all of the members appreciate the heavy nature of the duties of the president of this organization. Therefore I move that we extend a vote of thanks to our retiring prsident, MAJOR JAMES BROWN, who has presided so ably at these meetings.

(The motion, duly seconded, was carried by a unanimous rising vote accompanied by applause.)

Upon motion, duly seconded and passed by the membership, the seventy-first annual meeting of the American Fisheries Society was declared adjourned at 5:00 P. M.

In Memoriam

M. J. Bottinelli, Kellogg, Idaho

Merrill W. Brown, Sacramento, California

Robert E. Ellsworth, Alpena, Michigan

George Gibbs, New York, New York

M. L. Hutton, Ames, Iowa

Gardner Poole, Boston, Massachusetts

George T. Slade, New York, New York

James H. Vogt, San Francisco, California

Dennis Winn, Nashua, New Hampshire

PART II
PAPERS

CAN THE FISHERIES SUPPLY MORE FOOD DURING A NATIONAL EMERGENCY?[1]

ELMER HIGGINS
U. S. Department of the Interior, Fish and Wildlife Service, Washington, D. C.

ABSTRACT

The yield of our American fisheries can be increased 46 per cent during a National emergency. The 1938 yield of the fisheries of the United States and Alaska was 4,254,000,000 pounds. Under conditions of a war-time emergency necessitating greater supplies of food and industrial by-products, this yield could be increased to 4,628,000,000 pounds in 3 or 4 years and eventually a sustained total of about 6,200,000,000 pounds could be produced each year. Minor modification of methods of utilization will permit an increase in food production from the fisheries of 86 per cent.

The increases would necessitate an immediate application of scientific management measures and a partial diversion of certain species from non-food to food uses. Included in the estimated ultimate increase also is the assumption that the greater demand and higher prices for fishery products will make profitable an extension of the fisheries to more distant grounds and that certain discarded or partially utilized species in both marine and fresh waters will find a place either on the markets or in the manufacture of fishery by-products. No Government subsidies to stimulate increases in fishing effort or to provide for expansion of processing and transportation facilities are contemplated, for subsidies will lead to unwarranted expansion and post-emergency depression. The estimated increases can take place through normal economic processes.

The gross yield of the American fisheries can be increased 46 per cent! The total yield of our fishery industry in the United States and Alaska in 1938 was 4,254,000,000 pounds. Under conditions of a war-time emergency this yield could be increased to 4,628,000,000 pounds in 3 or 4 years, and a few years later could be increased to a sustained total of 6,200,000,000 pounds of food and industrial products.

From this great harvest of the fisheries, the Nation utilized 1,921,000,000 pounds as human food in 1938. With relatively simple changes in method of utilization plus potential increases in total yield, food production may be raised to 3,582,000,000 pounds, an increase of 86 per cent!

These are startling statements. To some, who regard the sea as an unlimited and inexhaustible source of wealth, they will be a disappointment; to others, who realize the limitations and difficulties of rapid industrial expansion, the total will be surprisingly large. These statements may be surprising also because they come from biologists who usually study fisheries that are already suspected to be suffering from overfishing and their researches usually confirm such fears. Strange as it may seem, the estimate of the possibility of increasing the total

[1]Based on a report presented to the Fishery Advisory Committee at Washington, D. C., January 30, 1941.

fishery harvest nearly half again comes from a corps of biologists who themselves are keenly aware of the present fact or the future danger of depletion of certain important fish supplies.

In assembling material for the consideration of the Fishery Advisory Committee, inquiries were addressed to the heads of our fishery research sections in each of the major districts of the country,[2] requesting them not only to estimate the extent of visible fish stocks that currently are available, but to speculate somewhat freely about supplies of fish that might become available even though there is little exact information on their extent. By temperament these men are naturally cautious; their estimates in some cases border on real conservatism. Others are more optimistic, but all of the material here presented embodies the known facts and the best *"educated guess"* presently available. Moreover, immediate increases and ultimate sustained increases in yield have been considered species by species in each locality against the background of known production for a long period of years. The total estimates for a region, therefore, are not a lump figure but are the summation of anticipated decreases as well as increases in yield during the next few years, and the possibilities of industrial expansion have been given some consideration. The tables presented herewith showing the various items that make up these estimates will outline the strengths and weaknesses of the American fisheries.

I have headlined the estimate that the yield of the American fisheries may be increased by 46 per cent. Before we consider the details let us classify the sources from which or the means by which these increases may be realized. None of the estimates contemplate letting down the bars of wise conservation practices, of mopping up or mowing down the standing crop of fish supplies for the sake of an immediate market and at the cost of future yields, but all of them contemplate a natural and healthy development of the fisheries on the basis of permanent or sustained yield long in the future after any National emergency will have passed. Fortunately, the mistakes of the last war still linger in our memory, when through relaxation of reasonable protective regulations the existing fish supplies suffered injuries from overfishing which take years to remedy. What doth it profit a man or a Nation of it save the whole world and lose its own land or the natural resources that make the land worth defending? The emergency must be desperate indeed to make it necessary almost to destroy the fishery resources for the sake of augmenting temporarily the food supply.

There are a number of current practices which could be modified to increase the yield of the fisheries without materially increasing the capital outlay or the cost of operating the existing fishing industry.

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[2]Estimates of potential production from the various coastal regions and the Great Lakes were received from Wm. C. Herrington, R. A. Nesbit, M. J. Lindner, O. E. Sette, F. A. Davidson, John Van Oosten and P. S. Galtsoff.

These may be listed briefly as follows: (1) Management of the fish supply; that is, the regulation of fishing so as to produce a maximum yield in pounds from an abundant standing crop composed of individual fish that have reached their maximum growth and permit sufficient natural reproduction to maintain the supply. Many of our fisheries are suffering from lack of management of this sort; the fishery is too intensive, it removes too many fish too soon, and while they are too small. While the adoption of sound management practices would result in moderate curtailment of the catch during the first year, the yields would increase in the second, third, and fourth years and would become stabilized at a higher permanent level thereafter. (2) The utilization of waste fish that are now destroyed by current methods of fishing for more valuable species, but which could be marketed immediately in considerable quantities and without additional cost in gear or labor if suitable markets for them were established. (3) The production of species now unutilized or only slightly utilized by existing fisheries either because they are not popular in the markets or because their value is low. (4) Farming methods applied especially to shellfish culture.

A second classification of possible means of increasing the yields of the fishery, but which could be accomplished only by a material outlay for equipment and additional labor and which would, in some cases, actually require the creation of new fishing fleets, includes: (1) The extension of fishing grounds to areas not now exploited by the American fisheries, for example the Grand Bank, Davis Strait, subtropical waters of America, Bering Sea, and the Gulf of Alaska; (2) increased fishing effort—more boats and shore facilities, and more fishermen—operating on grounds that are now only partially exploited.

It is clearly recognized that, with the exception of improved management of the fish supplies now exploited and suffering from overfishing, these increases in yield can occur in a healthy and satisfactory way only through economic forces that are effective even in times of peace. Aside from variations in the real abundance of the fish supply, demand, price, and cost of production and distribution are the chief factors that control the production or the extension of the fisheries. Under conditions of a war-time emergency we may anticipate an increased demand and slightly increased prices. If the emergency becomes extreme prices might rise sharply. Yet all of the extensions classified above, with the single exception of management of the fisheries, can occur only if demand and price rise sufficiently to balance the increased cost of production. With all our patriotic sentiments, the profit motive will be a powerful incentive for fishing harder, longer, or farther afield. Omitted entirely is the possibility of increased production by means of direct Government subsidy. If we are to avoid the dangers of post-war depression or collapse no subsidy is justified during war time, except under conditions of extreme emergency, that is not justified also during peace time.

But, under the conditions of increased demand and higher prices the expansion of the fisheries is limited by the natural abundance of the fish themselves. Assuming that all economic conditions are favorable to a rapid and extensive increase in the machinery of capture and of distribution, that markets are available for less popular species, and that profits will be possible even under war-time conditions, let us examine region by region the estimates of possible increased yields of the fisheries as limited by the natural abundance of the fish supply.

Table 1 is a summary of the present and the estimated future production of the fisheries of the United States under emergency conditions for the various sections of the coastal and interior waters and for the oyster industry of the entire country. It requires considerable temerity to present these figures in black and white for there is a finality about the printed word which implies a degree of accuracy these estimates cannot possess. The detailed tables for each section following this one will show internal evidence of their reliability. As stated before, these estimates are the best "educated guess" of men who are best able to risk an estimate, but balancing them together I am inclined to give considerable weight to the estimates of the total production of the entire country under the conditions that apply.

The first column is soundly founded on the former Bureau of Fisheries' published records of production in 1938. We have considered the potential yield under two headings: "Immediate" and "Sustained, or ultimate." The immediate yield is the estimate of possible production during the next 3 or 4 years, while the sustained yield is what may be anticipated for an indefinite future.

The tremendous increase in possible future yields of the North Atlantic fisheries, nearly three times its present production, is predicated on the assumption that economic conditions will favor considerable expansion of the fleet and a great extension of the fishing grounds to include, for instance, the Grand Bank and Davis Strait. Ordinarily, there is no way of estimating the future production of a fishery that is not now exploited somewhere near its limit. In this case, however,

Table 1.—Estimated fishery production of the United States under emergency conditions

[In millions of pounds]

Region	Present (1938 base)	Potential			
		Immediate	Percentage change	Sustained (ultimate)	Percentage change
North Atlantic	623	993	59.3	1,827	293.2
Middle Atlantic and Chesapeake Bay	462	484	4.2	733	58.6
South Atlantic and Gulf of Mexico	602	602	0.0	1,050	74.4
Alaska	799	723	—9.5	729	—8.8
Pacific (North)	222	272	22.5	264	18.9
Pacific (South)	1,295	1,295	0.0	1,295	0.0
Great Lakes	82	88	7.3	121	47.6
Mississippi River and tributaries	82	82	0.0	82	0.0
Total (excluding oysters)	4,167	4,539	8.9	6,101	46.4
Oysters	87	89	2.4	99	14.3
Grand Total	4,254	4,628	8.8	6,200	45.7

we already have the long record of production of cod and haddock taken on these grounds by the fishing vessels from France, Portugal, and Great Britain. This estimate, therefore, includes the harvesting of this supply by the American fishery.

There are other notable items in the table; for example, the considerable increases in the Middle Atlantic, South Atlantic, the Gulf of Mexico, which are made up largely of an extremely speculative item of future yields of menhaden which is at best a very doubtful guess. There is a notable increase also in the Great Lakes region, a region we have always regarded as suffering from the more advanced stages of overfishing. The increases here, however, are anticipated largely as a result of improved fishery management and the exploitation of species not utilized at present. The estimate includes even a reduction in yield of some of the more popular species. Another surprising item in the table is the estimate of no increase in the Pacific Coast, southern section, which includes California waters. This may be in part the result of the natural conservatism of the estimator, for undoubtedly better utilization of under-exploited species in these waters is possible. As will be brought out later, a considerable increase in food production without increasing total landings in California can be secured.

Turning now to the details of estimates of various sections, Table 2 shows the present and estimated future production of fisheries of the North Atlantic area. In this and other regional tables I have inserted in the last column key numbers which refer, as shown in the footnotes, to the various means by which the anticipated increases may be real-

Table 2.—Present (1938) and estimated production of the fisheries of the North Atlantic area

[In millions of pounds]

Species	Present (1938) catch	Potential		Method (see footnotes)
		Immediate	Sustained (ultimate)	
Haddock	158	237	350	1, 5
Cod	118	142	620	1, 4, 5
Redfish	65	65	75	4
Flounders	46	56	94	1, 4
Pollock	40	40	71	4
Whiting	25	25	60	4
Hake	24	24	50	4, 5
Cusk	8	8	12	4
Wolffish	3	3	6	4
Halibut	2	2	12	5 (1, 4)
Mackerel	39	39	75	4 (5)
Herring	21	45	75	2, 4
Swordfish	2	2	4	4
Tuna	2	2	5	4
Lobsters	11	17	18	1
Clams	18	31	45	4, 6
Other species (except oysters)	41	255	255	2
Total (excluding oysters)	623	993	1,827	....

[1]Conservation and management methods.
[2]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

Table 3.—Present (1938) and estimated production of the fisheries of Middle Atlantic and Chesapeake Bay areas

[In millions of pounds]

Species	Present (1938) catch	Potential		Method (see footnotes)
		Immediate	Sustained (ultimate)	
Alewives	24.2	19.2	40.0	1
Bluefish	1.7	1.7	3.0	3
Butterfish	11.7	9.7	15.0	3
Cod	10.9	14.9	15.0	4
Croakers	52.0	60.0	60.0	3, 4
Flounder	15.8	10.8	25.0	1
Grayfish	0.1	2.0	2.0	2
Hake	0.4	2.0	2.0	5
Mackerel	3.9	2.8	5.0	4
Menhaden	172.0	172.0	344.0	4
Scup	9.8	29.4	29.4	4
Sea bass	2.5	1.5	4.0	1, 5
Shad	7.8	5.8	20.0	1
Sharks	0.5	2.0	2.0	2
Sea trout	21.5	16.5	30.0	1
Striped bass	3.1	2.1	5.0	1
Whiting	10.2	15.2	15.0	3, 4
Other species	113.9	116.2	116.2	2
Total (excluding oysters)	462.0	483.8	732.6	....

[1]Conservation and management methods.
[2]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

ized. These are the methods mentioned earlier. It will be seen that the large increases are in cod and haddock, which can be accomplished in part by better management of the fish supply to secure the maximum poundage of the stock present on the grounds, but in large part also from the extension of the fishing grounds to the eastward. This extension of grounds will not involve a greater removal of fish from these grounds than have been taken in the past, but with the failure of European nations to utilize these fisheries of the high seas they should be available to the American fisheries.

The second notable increase is under the heading "other species." This is made up largely of possible landings of a number of trash fish now destroyed by the trawl fishery, such as squirrelfish, skates, hake, goosefish, and dogfish and other sharks, with some increases of whiting and herring through better utilization of the supply.

Table 3 outlines the present and anticipated yields from the Middle Atlantic and Chesapeake Bay areas. Here the dominant increases are from menhaden, and again the figure given is quite speculative, and some other species which are now wasted in the course of regular fishing. You will note that the anticipated increase from the shad fishery will result from the application of sound conservation and management methods, but that the immediate application of such methods will result in a restriction of the current catch for a period of 3 or 4 years.

The estimated production of the fishes of the South Atlantic and

Gulf Coasts presented in Table 4 show two notable increases in yield. The first is menhaden, which is admittedly highly speculative, and in this case would entail also additional construction of vessels and greater intensity of the existing fishery. The second is a great increase possible in the shrimp fishery which is the most important source of sea food in this region. This increase, the estimator believes, can be brought about by a complete overhauling of existing fishery regulations and the adoption of a more rational program of fishery management.

The picture of the Alaska fisheries as presented in Table 5 is a little confusing, for strangely enough the estimators anticipate a smaller yield in the future than in 1938. The chief reason for this apparent decline is that the year 1938 is not a suitable basis for fair comparison, for that year produced an all-time record catch in Alaska, particularly from the salmon which are cyclic in yield. If potential yield were compared with 1937 or 1939 the picture would be considerably changed. Furthermore, despite the fact that Alaska is regarded as a virgin territory, the fisheries were perhaps the first industry to develop on a major scale, and they may now be regarded as mature; that is, they utilize the salmon and herring resources particularly to their fullest extent under a system of fishery management that has already proved its value and effectiveness. Undoubtedly there are unutilized fish resources in Alaska that do not show in this table, for they are included under the all-inclusive heading "other species." The estimators believe, however, that these unexploited resources are relatively unimportant as compared with the great fisheries already developed

Table 4.—Present (1938) and estimated production of the fisheries of the South Atlantic and Gulf of Mexico areas

[In millions of pounds]

Species	Present (1938) catch	Potential		Method (see footnotes)
		Immediate	Sustained (ultimate)	
Bluefish	6	6	8	5
Croaker	7	7	21	2
Drum, black	2	2	4	3
Drum, red	3	3	6	1
Kingfish ("King mackerel")	4	4	10	5
Menhaden	303	303	500	4 (3, 5)
Mullet	36	36	50	3
Sharks	4	4	20	2
Spanish mackerel	7	7	10	5
Spot	6	6	18	3
Sea trout (gray)	5	5	5	..
Sea trout (spotted and white)	7	7	10	3
Crabs	26	26	50	1
Shrimp	140	140	250	1
Other species (except oysters)	46	46	88	2
Total (excluding oysters)	602	602	1,050	..

[1]Conservation and management methods.
[2]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

Table 5.—Present (1938) and estimated production of the fisheries of Alaska

[In millions of pounds]

Species	Present (1938) catch	Potential		Method (see footnotes)
		Immediate	Sustained (ultimate)	
Salmon (all species)	590	572	578	1
Red	234	239	241	1
Pink	236	211	215	1
Coho, king, chum	120	122	122	1
Cod	1	8	8	5
Herring	180	110	110	1
Halibut	20	22	22	1
Clams	1	1	1	6
Crab	1	1	1	5
Shrimp	1	1	1	..
Other species	5	8	8	2
Total	799	723	729	..

[1]Conservation and management methods.
[2]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

and that, therefore, only a relatively small amount of additional food supplies can be obtained. A later table will show how greater benefits might be secured from the gross catch presented here.

The picture of the fisheries in the North Pacific area; that is, Washington and Oregon, presented in Table 6 is somewhat more optimistic, although here again the individual items of increase are comparatively small. The figures presented for the flounder include other bottom fish taken in the trawl fishery and show a considerable increase, for this fishery is not fully developed and many species which occur in moderate abundance have real food value and can be marketed more

Table 6.—Present (1938) and estimated production of the fisheries of the North Pacific area

[In millions of pounds]

Species	Present (1938) catch	Potential		Method (see footnotes)
		Immediate	Sustained (ultimate)	
Salmon (all species)	60.4	91.0	89.4	1
Pilchard	87.0	87.0	87.0	..
Shad	0.5	5.5	5.5	3
Carp	0.1	3.0	1.0	3
Flounder	5.3	7.5*	7.5*	2, 5
Sharks	0.6	5.0	1.0	2
Halibut	23.5	25.9	25.9	1
Clams	2.2	2.8	2.8	6
Crabs	9.0	10.0	10.0	3
Other species	33.9	34.0	34.0	2
Total (excluding oysters)	222.5	271.7	264.1	..

*Including other bottom trawl fish.
[2]Conservation and management methods.
[3]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

extensively. Note that the shad is relatively unappreciated in the Pacific Northwest, but can yield a considerable additional quantity of food. Again, the figures for the base year 1938 are deceiving when considering the possible increase in the salmon fisheries, for 1938 is the off-year for the pink salmon in Puget Sound and moreover produced the lowest catch in that region for a 10-year period. Normal production of the salmon, therefore, is considerably higher than the base year given, and hence the increase in the salmon fishery of this region is much more apparent than real.[3]

As indicated in the discussion of Table 1, no increase has been estimated for the California fisheries and no table is presented therefore, but a later table will show additional potential food supplies.

The fisheries of the Great Lakes presented in Table 7 rank small in total yield among the other sections of the country, along with the fisheries of the Mississippi River and its tributaries,[4] which are of about equal magnitude, but have unique importance because they yield a particularly desirable quality and kind of fish for inland markets, and can be distributed in prime condition at minimum transportation

Table 7.—Present (1938) and estimated production of the fisheries of the Great Lakes region

[In millions of pounds]

Species	Present (1938) catch	Potential		Method (see footnotes)
		Immediate	Sustained (ultimate)	
Blue pikeperch	8.7	6.0	12.0	1
Burbot	0.4	0.7	1.9	2
Carp	4.9	7.0	10.0	3
Catfish and bullheads	0.8	0.9	0.9	3
Chubs	5.9	4.0	6.0	1
Cisco	0.8	0.3	0.3	1
Goldfish	0.2	0.4	0.5	2
Lake herring	20.5	25.0	30.0	1, 5
Lake trout	9.4	9.5	9.5	1
Sauger	0.9	0.8	1.0	1
Sheepshead	3.4	4.0	4.0	3
Smelt	1.8	3.6	10.0	3
Suckers	5.0	7.5	10.0	2, 3
White bass	0.7	0.8	1.0	3
Whitefish	3.3	3.0	3.0	1
Yellow perch	8.0	8.0	8.0	1
Yellow pikeperch	5.0	5.0	10.0	1, 5
Other species	1.5	1.7	2.5	2, 3
Total	81.2	88.2	120.6	..

[1]Conservation and management methods.
[2]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

[3]As evidence of the dangers of prediction, consider the great and unexpected increase in the catch of Columbia River salmon in 1941. It may well be, however, that the cream has been skimmed from this crop by a too-intensive fishery and that future cycle years will revert to a more normal mediocrity.

[4]With the impoundment of vast water areas in the Tennessee River, production of carp, buffalo, and other rough fishes and also of finer fishes such as pikeperch amounting to 3-5 million pounds a year is a distinct possibility.

costs. Minor increases among the great many species taken, which are unimportant in themselves, aggregate a considerable quantity of additional food. Here, perhaps more than in any other section, improved management methods for getting the most out of the available supply are most important. Considerable increases in a great many species can be secured by preventing the catching of undersized fish and leaving them in the water until full growth is achieved. Some areas of Lake Superior are relatively unexploited and some increase in lake herring can be taken from this region. The smelt is a relatively unutilized species in the Great Lakes, but this species has increased enormously since its original introduction about twenty-five years ago and, if market outlets could be found, it would yield 10,000,000 pounds.[5] Some areas now closed to commercial fishing could produce limited yields of certain species without injuring the angling resources. The other increases are made up largely from the utilization of less popular species of so-called rough fish.

An important source of food in the United States and one which would be particularly valuable under war-time conditions, when conceivably the fisheries of the high seas would suffer serious interference, is the oyster fishery on the Atlantic, Gulf and Pacific coasts. Table 8 presents a summary of production in the oyster fisheries giving actual production in 1928 and 1938 as compared with potential production in the immediate future and the sustained yield. You will note that production has suffered a serious decline in the past decade. Production could be increased immediately by throwing on the market some 3,000,000 pounds of oyster meats taken chiefly from the reserve stocks of the oyster growers, but the great permanent increase in production must come about through the adoption of farming methods. As compared with the fisheries for other species, where a waste of about one-third is involved, the production of oysters as represented in this table consists entirely of meats or 100 per cent food. Moreover, the dietary quality of oysters makes them particularly important in sustaining the health of a country at war.

In glancing hastily over these tables you probably have not had time to consider the details of the methods required for securing this additional food supply from the fishery resources. Table 9 presents a summary of the anticipated or potential increases in the yield of the fisheries in the various sections of the country according to the method chiefly responsible for the increased harvest. Column 1 represents the anticipated increases of yields over 1938, resulting from the adoption of sound conservation and management methods. While such methods would result in a reduced catch for the first year, the effects would be felt in the second, third and fourth years and would reach their full possibilities in from four to seven years depending upon the rate of growth of the particular species. Such a method would produce an ad-

[5]Unreported production including the catch for home consumption may equal this figure at present and the total doubtless could be increased proportionately.

Table 8.—Production of oysters in the United States in 1928 and 1938 and estimated potential production

[In millions of pounds]

Region	Actual production		Potential production			
	1928	1938	Immediate[1]		Sustained[1]	
North Atlantic	9.4	8.6	9.5	(10.5)	11.1	(29.1)
Middle Atlantic	39.5	16.1	16.6	(3.1)	17.4	(8.1)
Chesapeake	60.3	33.4	33.4	(0.0)	40.1	(20.0)
South Atlantic and Gulf	45.6	19.7	[2]20.4	(3.6)	21.7	(10.2)
Pacific	0.7	[3]9.1	9.1	(0.0)	9.1	(0.0)
Total	155.5	86.9	89.0	(2.4)	99.4	(14.3)

[1]Percentage increase over 1938 production indicated in parentheses.
[2]Increase from Gulf of Mexico only.
[3]Increase from 1928 to 1938 due to importation of the Japanese oyster.

ditional 270,000,000 pounds of fish without expansion of the fishing industry, and without additional boats or gear. Indeed such a yield would be produced more economically, for one of the methods of building up the fish supply is the reduction of the intensity of the fishery and hence this yield could be produced with fewer units of gear and smaller operating costs. The adoption of sound methods of management is not a war time emergency measure. They should be applied immediately to all the fisheries that are already suffering from overexploitation and they should be extended to all other fisheries as our knowledge of the need and the particular method increases.

Column 2 shows the increase of 324,000,000 pounds that would be immediately available through the utilization of waste species not extensively marketed at the present time, but caught by the present fishery. This addition to the food supply likewise would entail little expense in labor, gear, or equipment, but it can only be realized economically if markets are created for these products.

Column 3 showing an estimated increase of 65,000,000 pounds represents the result of an intensification of the present fishery for those

Table 9.—Potential increase yield of the fisheries of the United States and Alaska, listed according to method of obtaining the increase[1-6]

[In millions of pounds]

Region	Method of increase						
	1	2	3	4	5	6	1-6
North Atlantic	121	238	....	281	550	14	1,204
Middle Atlantic and Chesapeake Bay	49	6	11	202	3	....	271
South Atlantic and Gulf of Mexico	137	72	31	197	11	....	448
Alaska	—80	3	....	.....	7	1	—69
North Pacific	31	1	7	.....	1	1	41
Great Lakes	12	4	16	.....	7	....	39
Oysters	..	..	....	.....	....	12	12
Total	270	324	65	680	579	28	1,946

[1]Conservation and management methods.
[2]Utilization of waste.
[3]Intensification of present fishery.
[4]Greater production minor species.
[5]New grounds and new fleet.
[6]Farming methods.

species now relatively unutilized. It could be produced in large part without increases in the fleet or great expense of operation.

Column 4, showing an increased yield of 680,000,000 pounds, represents production of minor species for which little or no market exists at the present time. This quantity likewise could be produced with only moderate increase in operating cost.

Column 5, showing an increased yield of 579,000,000 pounds, represents the production of new fleets exploiting new fishing grounds and can only be accomplished at great financial outlay. Unless economic conditions undergo an upheaval which we cannot now foresee, the addition of this quantity to the fishery harvest is only a remote possibility.

Finally, Column 6 represents an addition of 28,000,000 pounds as a result of the adoption of modern farming methods applied particularly to oysters and other shellfish. To some extent this increase in yield could be accomplished with only minor additional costs of operation. With the development of suitable markets the production of such a yield would afford a considerable opportunity for labor.

So far we have considered the gross yield, present and potential, of the fisheries of the United States under war-time or reconstruction economy. We all remember the old slogan of the last war, "Food will win the war." Probably that slogan will not be revived, for conditions now are vastly different from what they were in 1914 to 1918, but in assessing the possibilities of increased production from the sea under emergency conditions it would be reasonable to reconsider these figures in terms of actual food. Some of our fisheries are prosecuted solely for the production of non-food items; that is, products used in the arts and industries or indirectly as human food through the intermediary of stock feeding and the like. Assuming that a third of the total weight of the fish landed in the round is non-edible and is wasted so far as actual food value is concerned, Table 10 is presented showing the estimated present and potential production of food and non-food fisheries. All of the waste from food fishes is of course a potential non-food item, but such waste is widely scattered among the various centers of production and probably cannot be assembled in volume large

Table 10.—Estimated net quantities of food and non-food production of the fisheries

[In millions of pounds]

Item	Present (1938) production			Potential production		
	Total	Food (net)	Non-food	Total	Food (net)	Non-food
Salmon	650	455	.....	667	467	200
Herring	203	20	175	185	93	92
Pilchard	1,110	190	839	1,110	777	333
Menhaden	485	.....	485	844	.....	844
All others	1.806	1,256	48	3,394	2,245	1,149
Total	4,254	1,921	[1]1,547	6,200	3,582	2,618

[1]The difference between the present total production and the sum of the net food and non-food production, amounting to 786,000,000 pounds, is very largely unutilized waste.

enough for economical manufacture. However, some food fishes, such as the pilchard and the herring, are fished primarily to produce meal and oil. They represent a food resource at present not fully utilized, which could be made available under proper conditions.

If 75 per cent of the catch of herring were marketed as food, we should have a potential net yield of 93,000,000 pounds from this source. If all of the Pacific pilchards or sardines were canned, we should have a potential food production of 777,000,000 pounds. Since these fisheries are highly concentrated in a few localities the waste from the food manufacture could be utilized. This waste from the herring fishery would amount to 92,000,000 pounds and from the pilchard fishery 333,000,000 pounds of by-products in addition to food products. If all the salmon waste in Alaska were recovered we should also have 200,000,000 pounds of raw material for non-food by-products in this fishery.

Since we had a net production of 1,921,000,000 pounds of food from the fisheries in 1938, with these relatively simple changes in method of utilization plus the potential increases in yield under the conditions outlined above, we can have a potential production of 3,582,000,000 pounds of food from the fisheries, or a net increase of 86 per cent.

It is reassuring to know that if worse comes to worst we can rely upon a 46 per cent increase in the total products of the sea with an 86 per cent increase in food production from the fisheries. Since the protein food from the fisheries ranks third among all sources of protein food for the nation, its importance in National defense must not be underestimated. The contribution from the sea and from the men who go down to the sea in ships ranks high among the elements of internal strength of our Nation.

THE USE OF THE SCALES OF RAINBOW TROUT (*SALMO GAIRDNERII*) TO MAKE DIRECT COMPARISONS OF GROWTH

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Abstract

No one has apparently made use of efficient statistical procedures for the "back-calculation" of the growth of fish from the measurements of the scales. If it can be shown that the scale provides an unbiased estimate of the length or "size" of the fish, then there is no real necessity for the conversion of scale size into body size for comparisons of the growth. A study of data obtained from the rainbow trout population of Paul Lake, British Columbia, showed that scale size could be regarded as an unbiased estimate of the length of immature 2-year-old male and female rainbow trout under the ordinary conditions of sampling by angling. An example is given to show how the growth of rainbow trout in 4 separate years could be compared by the direct use of the scales. It is known from previous studies that a significant reduction in size occurred during these years. A corresponding reduction in the size of the scales was also found. It is suggested that the method provides a direct index of the growth of the fish which can be used to compare growing conditions from year to year.

Introduction

Measurements of the scales of fish are often used to calculate the growth over periods of time previous to the time of capture. The subject was reviewed thoroughly by Van Oosten (1929) in connection with an investigation of the relationship between the growth of the scale and the body in the lake herring (*Leucichthys artedi*). Most fishes show a high correlation between the growth of the body and the growth of the scale, and the relationship is usually linear. Although in some fish the relationship appears to be non-linear it is usually regarded as sufficiently near linearity to be treated as such. The assumption of a linear relationship between body length and scale length permits a fairly simple "back-calculation" of the growth of the fish. The usual procedure is to make use of the ratio between body length and scale length at the time of capture and the scale length at some particular point on the scale, usually an annulus, to determine the body length at that particular point in the life history.

Various types of correction factors often are arbitrarily employed to adjust for the fact that the scale does not form until the fish has reached a certain size. Adjustments may also be made for an apparent change in the relationship between body growth and scale growth. Hile and Jobes (1941) gave an example of the recent use of such arbitrary correction factors. Although Buchanan-Wollaston (1936) has drawn attention to the more efficient method of linear regression for

handling such problems, no one apparently has made use of his suggestion.

If it can be shown that the scales of rainbow trout provide an unbiased estimate of the length or "size" of the fish, then there is no real necessity for performing all of the computations required to convert scale size into body size. Comparisons could be made directly between the growth of fish under different conditions by means of the scale measurements themselves. For example, it is not necessary to convert measurements of two objects, one 10 inches long and the other 15 inches long, into metric equivalents in order to judge that one object is longer than the other. The problem hinges mainly on the question of the bias of the scale measurements as an index of body size under varying conditions of sampling. Several authors have pointed out that differences between age groups or between the sexes or differences traceable to the season of capture operate as selective factors with the result that scale size may provide a biased estimate of body size under the different sampling conditions, and thus provide undependable measures of fish length.

The purpose of the present paper is, therefore, threefold: (1) To show how efficient statistical methods may be employed in problems concerning the calculation of growth from scale measurements. (2) To investigate the question of the bias of scale measurements as estimates of body length under various sampling conditions. (3) To show how the scale measurements may be used directly to compare the growth of rainbow trout over a period of 4 years.

The Bias of Scale Measurements

A representative set of data was obtained from the Paul Lake catch records by selecting 144 individuals at random. The sample consisted of 4 immature males and 4 immature females of the 1931, 1932, and 1933 year classes caught by angling 15, 16, 23, 25, 26, and 27 months after hatching. This sampling provided 72 males and 72 females to test for differences due to sex, 48 individuals from each of 3 year classes to test for differences due to varying conditions in the different calendar years, and 24 individuals caught in each of the 6 months to test for differences due to the selective effects of the angling fishery.

The length of the fish measured to the mid-fork of the tail and the length of the anterior radius of the scale to the margin, magnified 19.3 diameters, were first transformed to logarithms. An independent analysis verified the suggestion made by Buchanan-Wollaston (1936) that the mean and variance are correlated in such a way that the logarithmic transformation is necessary. The evidence is given in Table 1.

The transformed data were reduced using the standard methods of the analysis of covariance (Snedecor, 1940) and are shown in Table 2.

If the second-order interaction, $S \times B \times M$, in Table 2 is used as

Table 1.—The number of fish (N), *the median fork length in centimeters* (X), *the mean scale length in millimeters,* × *19.3* (Y), *and the variance of the scale length* (Vy) *of eight groups of rainbow trout from Paul Lake. Groups 1, 2, and 3 were caught by gill nets and seining in 1932 and 1933; the remaining groups consisted of immature fish caught by angling in 1932*

Group	*N*	*X*	*Y*	*Vy*
1	16	8	7.69	3.29
2	48	13	15.08	4.17
3	17	18	17.76	2.19
4	59	23	26.81	13.47
5	118	28	32.13	12.40
6	40	33	38.00	23.44
7	80	38	42.11	26.25
8	45	43	49.60	27.80

the estimate of experimental error to judge the significance of the factors, it can be readily shown, although the actual calculations are not worked out in detail here, that when adjustments are made for the differences in body length (X) the variations in scale length associated with sex, year class, and time of capture (M) are not significant. Likewise none of the first-order interactions is significant.

If the length of the scale is to be used to calculate the body length, it may be easily obtained from the regression equation derived from the data in Table 2. These data will provide the correction factors necessary for making adjustments in this particular situation. By plotting the data graphically it was determined that there was no need to regard them as non-linear; hence no correction for apparent change in the relationship between scale length and body length was used.

From the foregoing analysis it was decided that the scale provided an unbiased estimate of the body length under the main sampling conditions. It was concluded also that the scales could be used to compare the size of fish from one year to another. It should be pointed out, however, that the sampling error for scale length is significantly higher than that for body length; consequently either more scales would have to be taken from each fish, or the samples of fish would have to be larger in order to reach the same degree of precision as that obtained for a given number of length measurement. Scale measure-

Table 2.—The reduced data for the analysis of covariance of body length (X) *and scale length* (Y) *of male and female rainbow trout of 3 different year classes caught by angling in 6 different months*

Source of variation	Degrees of freedom	Sums of squares and products		
		Sx^2	Sxy	Sy^2
Total	143	1.196929	1.211491	1.540697
Sex (S)	1	0.000650	0.001095	0.001842
Year classes (B)	2	0.125488	0.076680	0.046857
Months (M)	5	0.660899	0.693025	0.735011
Interactions:				
$S \times B$	2	0.003549	0.002222	0.002935
$S \times M$	5	0.009112	0.012197	0.022648
$B \times M$	10	0.119740	0.124286	0.143981
$S \times B \times M$	10	0.024715	0.024565	0.045488
Sampling error	108	0.252776	0.277421	0.541935

ments are not as precise as length measurements and, therefore, are not as efficient. On the other hand it is possible that, even with lowered efficiency, scales could be collected by untrained individuals and would supply reliable estimates of the size of the fish in a given population.

A Comparison of the Growth of Rainbow Trout in Different Years

In order to provide an example of the use of scales to make direct comparisons of the growth of rainbow trout, 200 samples were drawn from the Paul Lake angling records for the years, 1932, 1933, 1934, and 1935. The samples were obtained by the statistical technique of restricted, random selection. The sampling was restricted (1) to immature fish (that is, no spawning mark was present on the scales), (2) to 2-year-old fish, and (3) to equal numbers of males and females, (25 of each in each year's sample). Since no sex difference was found in the preliminary study the last restriction is probably not important. The data obtained are shown in Table 3.

The analysis of the variation of the scale-length measurements in the different year classes is shown in Table 4. The original data in this investigation were not converted to logarithms, but this step should

Table 3.—The length of the scale (millimeters, × 19.3) to the second annulus of the scales of 25 male and 25 female rainbow trout in 4 year classes from Paul Lake. The totals for the sexes separately and combined are given at the bottom of the table

Year class							
1930		1931		1932		1933	
Male	Female	Male	Female	Male	Female	Male	Female
37	54	37	44	33	39	30	35
41	47	40	36	35	34	34	32
34	44	47	40	33	36	23	32
44	22	34	36	45	39	37	35
49	42	37	29	47	36	30	33
42	48	29	34	40	40	35	32
26	37	42	34	39	33	30	35
46	33	38	43	47	43	41	40
35	51	31	46	38	37	41	38
42	26	44	40	39	30	42	35
34	39	25	42	47	38	24	31
45	47	41	22	30	33	27	25
39	38	47	50	42	32	36	37
35	43	24	25	35	41	27	33
42	36	49	44	41	34	35	35
42	32	29	32	32	32	22	33
46	44	43	26	39	33	33	37
43	50	47	31	31	36	36	36
37	41	28	50	39	34	33	36
49	35	20	33	37	39	30	37
22	44	36	36	39	33	37	33
31	42	33	50	46	27	40	36
35	40	45	47	40	34	35	33
42	37	34	28	46	22	29	31
46	27	48	22	33	43	44	32
984	999	928	920	973	878	831	852
1,983		1,848		1,851		1,683	

Table 4.—The analysis of the variation of the scale size of rainbow trout in 4 different year classes

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	199	9,488.88	.....
Between years	3	905.54	301.85
Within years	196	8,583.34	43.79

$$F = \frac{301.85}{43.79} = 6.89 \text{ (highly significant)}$$

be taken if the *F-ratio* falls below the level of 1 per cent. Since there is a highly significant difference between the different year classes it may be concluded that the evidence indicated a downward trend in the size of the fish between 1932 and 1935 (see the totals at the foot of Table 3). Previous studies (Mottley, 1940 and 1941) have shown that both the length and the weight of this population of fish decreased significantly during the same period.

Conclusion

Although the measurement of a single scale from a comparable position on the body of each individual in a series of fish is not as precise as the measurement of the actual length of the fish, it can, nevertheless, be used as an index of the body length. Various sampling conditions may affect the size of the fish in a given sample, but in the rainbow trout of the Paul Lake population these conditions did not affect the relationship between body length and scale length. It may be concluded that the scale measurement can probably be used directly as an estimate of the size of the fish without any further correction. The method suggested by this conclusion, if proved generally applicable, has many practical advantages. By collecting scale samples sportsmen and resort owners, as well as fishery managers, can obtain a direct index of the growth of the trout which can be used to compare growing conditions from year to year. The samples can be taken at any time during the fishing season by the usual angling methods, and no elaborate measuring devices are needed in the field. It is possible that, if the weight of each fish is obtained along with a scale sample, that a coefficient of condition can aso be calculated.

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FRESH-WATER IMPOUNDMENTS

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Abstract

Several features of impoundments and reservoirs, either inherent or the result of operations at the dam, can reduce and limit the biological productivity of an impoundment and consequently the fish production of its waters. Among these characteristics are the stagnation of large masses of water, the removal of food materials in the waters drawn out of the reservoir, the limited lateral areas of shallow water around the margin of the impoundment, extensive fluctuation of water level, and continued and often heavy silting in of the bottom.

Water conditions in an impoundment usually are less stable and are often quite different from those found in comparable natural lakes.

The limitations of impounded waters for fish productivity can in part be offset by: (1) Controlling the draw-off (where such regulation is compatible with the major interests for which the impoundment is created) so that fairly constant water level will be maintained during the nesting season of the most desirable species of fish. (2) By judicious restocking (not overstocking, nor again promiscous stocking with all kinds of species) from hatchery or hatchery ponds with vigorous specimens of the desired species. (3) By the construction where feasible of lateral areas of shallow water of constant level and tributary to the main impoundment, in which adult fish can nest, young fish can find refuge and fish food can be produced. (4) By the use of various devices such as floating nests, floating shelters, the planting of exposed portions of the reservoir during low water. (5) By the artificial enrichment of soil and water with specific substances such as phosphates, seed meal and organic wastes, in such limited areas as seem to justify the expense of these procedures.

The pollution hazards to the impoundment and the characteristics of the tributary waters should be considered in advance of construction of the dam. Studies of existing reservoirs have shown that much stagnant water may be expected in most impoundments over 30 feet in depth, and that relatively small amounts of wastes having high oxygen demand and of many wastes from various municipal and industrial sources can become very serious hazards to fish life when poured into reservoirs where water conditions are necessarily less stable and often nearer the critical levels for fish life than in the average natural lake.

In the interest of fishing in the stream above the impoundment, within the reservoir, and in the stream below the impoundment attention should be given to the position of the outlet. Considering only the water conditions in the reservoir a draw-off from the bottom of sufficient magnitude to remove much or all of the stagnant water in the deep part of the reservoir would be preferable. Obviously, this volume of water can not be spared from most impoundments. If the flow from the outlet is small and intermittant these advantages to the reservoir water from a bottom draw-off decrease and the disadvantages to the stream below the dam become increasingly more evident. Stagnant water drawn from the lower levels of the impoundment can be a serious hazard to the fish in the stream below the dam. The low oxygen content of waters drawn from the lower levels of the reservoir constitutes one of the major hazards of such water. Water drawn from the bottom of the reservoir, or from any of the lower levels during the portion of the year in which water of low oxygen con-

tent is found in the deep part of the reservoir, should be properly reaerated by passing it over or through a system of baffles if proper conditions for fish life are to be maintained in the stream below the dam.

Those interested in fish must not expect any impoundment to be a perpetual source of boundless good fishing. The initial period of high productivity may be very short in some reservoirs, and longer in others but the decline will inevitably come unless man makes some adjustments which will create new food supplies and favorable growing conditions, for fish within the impoundment.

Introduction

Impoundments constructed to assure water for domestic use and irrigation have occupied important positions among man's engineering projects since ancient times, and as early as the Fourteenth Century, B. C. Rameses II of Egypt had a well-organized system of storage reservoirs in the Nile Valley. However, during the past 100 years and, particularly during the last 25 years, the advancing and complicated modern civilization has required that reservoirs wherever possible not only conserve water to meet domestic demands and to maintain irrigation, but to further industry, to expedite navigation, to control floods and to produce hydro-electric power. To meet various combinations of these needs many large impoundments have already been created, and many others are now authorized or contemplated. Revolutionary changes in the status of some of our natural inland streams have resulted, yet little attention has been given to fishery interests in these impoundments partly because this new expansion program has been developed so rapidly and partly because of the popular but erroneous assumption that the potential fish productivity of an impoundment is measured largely by cubic feet of water behind the dam.

Recent investigations of various impoundments have shown that these man-made bodies of water can be grouped into three classes: (1) The larger and deeper types like Elephant Butte Reservoir (Ellis, 1940) in the Rio Grande River, Norris Lake (Wiebe, 1938) in the Tennessee River, and Lake Mead (Nat. Res. Council, 1938) in the Colorado River. (2) Those of intermediate depth as Lake Keokuk in the Mississippi River (Ellis, 1937a). (3) The shallow type like Minerva Lake (Senning, 1939) in New York State. All of these types of impoundments although superficially resembling natural lakes, differ definitely both in physical and in chemical characteristics from natural bodies of water. Several of these peculiar characteristics of impounded waters have an important bearing on the development and maintenance of the fish fauna in the impoundment. Conditions that will develop in the reservoir can be predicted with considerable accuracy before the dam is built, if the composition of the waters tributary to the impoundment area and the type of dam to be constructed are known. Physical features of the impoundment produced by the construction of dam, and the removal of water from the reservoir at

times, which may or may not follow the natural stream cycle of flow and from levels quite different from the usual outlets of natural lakes, are among the major factors responsible for these differences between the impoundment and the natural lake.

As indicated above, the actual size of the impoundment is an important factor in determining both how much the waters will deviate from conditions expected in a natural lake of comparable size, and which differences will predominate. In general, small shallow impoundments approach pond conditions. The more extensive impoundments of shallow or moderate depth like Lake Keokuk in the Mississippi River and Wheeler Reservoir in the Tennessee River are dominated to some extent by the tributary river. The large, deep reservoirs designed primarily for storage capacity, which class includes most of the larger impoundments such as the Lake of the Ozarks in Missouri, Coolidge Reservoir in Arizona, Elephant Butte Reservoir in New Mexico, and Norris Reservoir in Tennessee, show the peculiarities of impounded waters most definitely. Major consideration in the present discussion is given therefore to the last group designated as the larger impoundments.

The studies on which this account is based have been carried forward with field parties from the Columbia, Missouri, Section of Water Quality Investigations of the Fish and Wildlife Service (and of the former U. S. Bureau of Fisheries).[1] Observations, samplings, and analyses have been made at 33 of the major impoundments in the United States during the 4 years prior to 1940, and 6 of these impoundments have been followed in a series of seasonal studies for 5 years.

Physical Characteristics of Impoundments

Most of the modern impoundments are produced by the construction of dams across natural river basins for reasons of efficiency. If storage capacity for municipal water supplies, irrigation, flood-control and hydro-electric developments be primary considerations the dam usually is placed across the narrowest and deepest section which will impound the maximum storage in the basin. On the other hand, if navigation be the major interest the dam ordinarily is erected across the section where minimum height of construction will give the maximum amount of slack water of proper channel depth for the greatest distance upstream. In some localities, notably in New England and in several of the more arid western States, small streams have been impounded primarily to produce small and usually shallow lakes for fishing and recreational purposes.

[1]The Bureau of Fisheries of the Department of Commerce and the Bureau of Biological Survey of the Department of Agriculture were transferred to the Department of the Interior, July 1, 1939. On July 1, 1940, the Bureau of Fisheries and the Bureau of Biological Survey were abolished and their respective functions transferred to a single newly-established agency, the Fish and Wildlife Service of the U. S. Department of the Interior.

Therefore, local conditions, combinations of interests to be served by the impoundment and specific engineering details vary and will determine the exact location of the dam and the resultant configuration of the reservoir. However, in nearly all impounds the dam which may be only a few hundred feet long, as the Shoshone Dam, which impounds Shoshone Lake in Wyoming, or miles long like the great Fort Peck Dam in Montana across the Missouri River, occupies the same general position with reference to deep water. That is, the deepest water in the reservoir is usually at or near the dam which rises abruptly and almost vertically from the bottom of the reservoir and projects above the surface of the water like a sheer cliff.

There may be deep holes in the reservoir, and in these depressions the depth of the water may be greater than the depth at or near the dam. However, because of the position of the dam as usually constructed the mid-channel or sagittal profile of the larger impoundments is essentially a right triangle, in which the right angle rests at the junction of the surface of the reservoir with the dam, and the hypotenuse extends from the bottom of the reservoir at the dam upstream to the upper limit of the back water. In ground plan, therefore, these impoundments are only "half-lakes" (Ellis, 1940) for the deepest water in most natural lakes is usually well off-shore with progressively shallower water arranged more or less concentrically around the central mass of deep water.

Consequently, since the dam passes through what would be the depth center of a natural lake, currents and flows in the reservoir and the resultant effects of these movements of water on the distribution of dissolved oxygen, the transportation of silt, the accumulation of organic debris, and other conditions vital to fish life, can be quite different in the impoundment from those usually found in natural lakes. For example, surface currents produced by wind, wave action, storms and sudden inflows of warm waters from the tributary streams moving down the impoundment drive against the dam over the deepest water in the reservoir. Thus the currents are reflected downward or backward instead of spending themselves in the shallows on the opposite shore as in a complete natural lake.

The position of the outlet is a second physical feature in which impoundments differ from most natural lakes. In general, fresh-water lakes have an inlet or inbound supply of fresh water from the surface run-off, snows and tributary streams, and a definite outlet. Otherwise concentration due to evaporation would produce a salt lake. Usually the outlet from a natural lake is a small stream that arises in the marginal shallows, and not in the deep central basin. Consequently the draw-off is from the surface of the average natural lake.

The outlets from industrial and storage impoundments are intentionally placed well below the surface, frequently near the bottom, to meet the needs of irrigation, water supplies, and power, so that the draw-off from an impoundment storing water for such purposes, re-

moves water from the depth center of the impoundment and at levels below the surface. The draw-off from an impoundment can also be controlled so that not only is the volume of outflow varied from time to time but the flow may be intermitten or constant as desired. All of these peculiarities of the impoundment outflow can affect the distribution of dissolved gases and other substances in the deeper portion of the reservoir, and therefore can produce conditions quite different from those in a natural lake with a fairly constant and uninterrupted surface outflow. In contrast, too, to the natural lake, surface water rarely leaves these larger impoundments from the surface of the reservoir, except at times when the reservoir is filled to capacity and overflow is permitted from the spillways on the crest of the dam.

Physical and Chemical Characteristics of Impounded Waters

Natural lakes over 30 feet in depth throughout the United States usually develop some sort of thermal stratification during the summer months with attendant changes in dissolved oxygen, relative acidity, carbon-dioxide content and other characteristics which play important roles in the maintenance of the aquatic fauna of the lake. In general, three bands of water may be found in a vertical section of such natural lakes during the warm season: (1) A surface zone (the epilimnion) of well-aerated but rather warm water extending downward from the surface some 15 to 30 feet depending upon local conditions. (2) A narrow middle zone (the thermoclinal zone) usually less than 15 feet in thickness, in which the water temperature falls rapidly and other water characteristics, particularly the dissolved oxygen content, may change abruptly. (3) A bottom zone (hypolimnion) extending from the thermoclinal portion to the bottom of the lake, and composed of cold water, usually low in dissolved oxygen and often carrying various decomposition products derived from the organic debris that settles to the bottom of the lake. Sometime during the fall or winter there is an overturn of the stagnant water at the bottom of the lake, this stratification is abolished, and the water becomes more or less uniform in composition throughout the lake at all depths, remaining so until warm weather returns (Birge and Juday, 1911).

The waters of the larger impoundments thus far studied, tend when undisturbed to follow the cycle of summer stratification and winter mixing just described for average lakes. However, combinations of conditions resulting from both the physical features of the impoundment and the removal of water during the draw-downs can modify or abruptly break up the lake type of stratification either in part or entirely. Consequently not only do the waters of some impoundments fail to show regular stratification but water characteristics may be quite different in any given impoundment for the same month during consecutive years. Water conditions in an impoundment, therefore,

are subject to more variation than in natural lakes. Sometimes the deviations from the lake type are beneficial, sometimes destructive to aquatic life. Two examples will suffice.

The position of the dam across the depth center of the impoundment and the constriction of the basin in the deep, adclaustral portion of some impoundments produce conditions favoring a very sudden turn-over of the deep mass of stagnant water in the impoundment, particularly if there be a sudden drop in the temperature of the intake water and if the inflowing current be augmented by a strong draw-off current. These abrupt turn-overs project large volumes of stagnant water from the bottom of the reservoir so rapidly into the surface zone that disastrous results to the fish of the reservoir often follow. A few years ago one of these sudden turn-overs killed thousands of fish in the Lake of the Ozarks, an impoundment in central Missouri (Ellis, 1937b).

The draw-off not only contributes to these turn-over catastrophes but can produce currents of varying magnitude, depending upon the amount and duration of the draw-down, in the deeper portion of the reservoir at all seasons of the year. By breaking the mid-summer thermal stratification these draw-off currents may prove beneficial to the aquatic life of the impoundment by removing some of the stagnant water from the bottom or hypolimnial zone and by drawing well oxygenated surface water deeper into the reservoir. It is well established that diffusion of dissolved oxygen from the surface water into the deeper layers of a lake or impoundment proceeds so slowly that it is of little significance in the reoxygenation of waters from which the dissolved oxygen has been removed. Therefore currents carrying well-oxygenated water to deeper levels are important in determining the quality of the water in the deeper portions of impoundments. Such currents moving well aerated surface water to deeper levels have been observed in Elephant Butte Reservoir (Ellis, 1940).

On the other hand, these draw-off currents may hasten equally well the downstream movement of an advancing mass of water low in dissolved oxygen, which develops near the upstream end of many impoundments in early summer (Wiebe, 1938; Ellis, 1940), into the well-oxygenated water left in the deep part of the reservoir from the previous winter mixing. It may be seen, therefore, that draw-off currents, particularly those produced by large draw-downs to meet emergency needs, can alter the distribution of both good and bad water in the deep part of the reservoir, and that these draw-off currents contribute to a much less stable state of the various water characteristics in the deeper portions of an impoundment than are usually found in the deeper parts of natural lakes.

Another group of water disturbances which can alter the physical and chemical characteristics of the waters in impoundments are produced by density currents, that is, by long masses of water differing from the surrounding waters in specific gravity, temperature, silt

load, salt content and dissolved oxygen. These masses of water originate at the main inlets and intrude themselves into the water of the reservoir at various levels. Some of these density currents may move for only a few hundred yards, or few miles at most, finally to be dissipated by dilution, sedimentation, changes in temperature and other factors, but not infrequently these density currents move through the entire reservoir and retain definite identity and position throughout the passage from inlet to outlet.

Although density currents have been observed in rivers, natural lakes and oceans, the closing of a stream by a dam thereby creating a large basin of deep slack water in which the inflowing waters from streams tributary to the reservoir can spread out or move forward with little interference from wave or wind action, together with the subsurface position of the impoundment outlet and the deep currents produced by the draw-off, combine to establish conditions favorable to the movement of density currents in many reservoirs.

Density currents carrying heavy silt loads are known as silt flows and have been noted in many reservoirs including Lake Mead and Elephant Butte Reservoir (Nat. Res. Council, 1938) and in Lake Wilson in the Tennessee River, before the erection of Wheeler Dam (Ellis, 1937b). Other density currents without conspicuous silt loads but with peculiar characteristics of dissolved oxygen, relative acidity or salt content have been reported from these and other impoundments (Nat. Res. Council, 1938; Wiebe, 1938; Ellis, 1940). However, density currents of all types can produce marked changes in portions of the water of a reservoir, and although these changes may be of only short duration in some cases, density currents can drop heavy silt loads, carry mine pollution, or reduce the dissolved oxygen, to the detriment of the fish fauna in the impoundment.

A fourth feature of impoundments which limits the production of fish within the waters of a reservoir is the small amount of permanent shallow water around the margin of the reservoir. From an engineering standpoint shallows offer little storage capacity and much loss by evaporation. Although lateral shallow areas do not interfere with the main engineering project, if construction costs and maximum storage capacity be considered, deep valleys or canyons with steep walls are preferred for reservoir basins. Consequently, the average impoundment offers little shallow water in which fish can nest, fish food can be produced, and young fish can find refuge from the larger predatory fish. This probem is complicated still further by the drawdown. Many reservoirs have some areas of shallow water suitable for nesting sites and for fish food production when the reservoir is well-filled, but these shallows are quickly emptied by even a small drawn-down. Fluctuation of water level consequently leaves the shallows exposed for a considerable portion of the year, preventing the aquatic plants, which play such an essential role both in food production and as fish shelters, from becoming established. Fish nests which

may have been built in these areas when flooded will also be stranded.

In this connection draw-downs made for mosquito control must also be noted. Many reservoirs in the warmer parts of the United States present serious malarial hazards to the adjacent human population in providing breeding places for the mosquito vectors of that disease. Small draw-downs made at frequent intervals during the mosquito season have been beneficial in some areas in partly controlling the mosquitoes in the shallow lateral portions of such impoundments. These changes in water level although of lesser magnitude than those resulting from the draw-downs for industrial and flood control operations, nevertheless affect adversely the use of the shallows around the margin of the impoundment as nesting areas, as safety zones for young fish and as sources of fish food.

Biological Productivity of Impounded Waters

Following the first flooding of a large reservoir basin the supply of natural fish food and therefore the biological productivity of the impoundment usually rises rapidly to a maximum within the first few years. It remains high for a year or more, and then declines rapidly during the next few years to a much lower level, which will be maintained approximately or which will decline still farther over a long period of years unless man intervenes with constructive procedures. However, even after the establishment of somewhat balanced adjustments in the reservoir, conditions regulating the biological productivity of the impoundment are always subject to abrupt interruption by changes in the amount and time of draw-off and by the character of the water entering the reservoir during these critical periods.

From the study of many impoundments throughout the country (Ellis, 1937b) the major sequence of these changes in food production and the attendant effects on fish productivity of the reservoir can be predicted with considerable certainty.

The initial filling of the reservoir leaches minerals from the soil which previously has been exposed only to surface waters, rains and snows, and nitrogenous material from the grasses, trees and other vegetation which are being submerged for the first time.

If the water entering the reservoir be ordinary river water, i.e., if the intake water is not polluted and does not carry noxious substances, and if the mineral content of the soil making up the floor of the new reservoir be free from toxic or harmful materials, the combination of substances leached from the soil and the submerged plant debris is very favorable to the production of water bacteria, microscopic plants and animals and various forms of small animals collectively termed plankton. Consequently, fish feeding on these types of food increase abundantly as do also the predacious game fish which in turn feed on the smaller fish. As the water in the impoundment nears the capacity level and the bottom fauna of aquatic insects such as mayflies and

midges becomes established the fish food production is augmented still farther from that source.

During this period which lasts for 2 years or more, depending upon several factors such as the rate at which the new reservoir is being filled and therefore the rate at which new land is covered for the first time, together with the extent and time of draw-downs if there be such, fish productivity rises rapidly and often exceeds the wildest dreams of the enthusiastic angler.

Unfortunately the very factors which make for high biological productivity in newly-filled reservoirs may limit or prevent high fish productivity if the impoundment be too small or too shallow. During the summer of 1936 the writer found the water in several recently-filled small artificial lakes in central South Dakota unsatisfactory to lethal for fish life. The conditions were the result primarily of the oxygen demand of various substances which had been leached from the soil and submerged debris or liberated by bacterial action in such quantities that the water was definitely acid in reaction, rich in carbon dioxide and critically low in dissolved oxygen. The same quantities of these same materials which had been leached from the basin and its contained debris if diluted as they would have been had these impoundments been deeper, would have provided much basic food for plankton. Through the plankton and small fishes food would have been provided for large warm-water game fish. Similar unsatisfactory chemical conditions in the waters of some of the smaller and more shallow impoundments built for recreational purposes in New York have been reported recently by Senning (1939).

However, in the larger impoundments sometime during the first 5 to 10 years after the initial closing of the impoundment, and often after only 3 to 5 years of high productivity, the fish production begins to decline, not infrequently with amazing suddenness.

The reasons for this decline are evident: (1) The supply of raw material from freshly inundated soil has been largely leached out. (2) Most of the organic matter, particularly the nitrogenous constituents in the submerged plant debris left in the basin, has been removed by bacterial action, decomposition and solution and either used in the production of fish food or lost with the waters leaving the reservoir. (3) The silting-in of the bottom has also begun and new conditions are being established at the bottom, which if the silting be rapid may definitely limit or reduce the bottom fauna in the deeper parts of the reservoir because of the unfavorable blankets of silt deposited there. (4) The large numbers of fish and other aquatic animals which developed during the initial period of high productivity are now consuming the food organisms at a more rapid rate than the declining supply of basic food will support. This lack of sufficient food particularly affects the larger predaceous forms. The consequent sharp reduction in sport fishing, particularly for the carnivorous game fish such as black basses, crappies, pikeperches and other rapacious feeders which

follows, usually is a rude surprise to those who have enjoyed the remarkable catches so common during the first few years of high productivity.

Once this peak of productivity due to the natural food supplies which develop immediately after the first flooding of the basin is past, the high natural productivity of the reservoir has never returned in the various impoundments which have been studied thus far. The new level of productivity usually is disappointingly low. During some subsequent years, especially after 1 or 2 years of very low water followed by a return to a higher level thus flooding areas which have lain fallow and on which while exposed to the sun and air weeds and other land vegetation have sprung up, encouraging natural increases in fish production have been noted. Unfortunately these rises in productivity are usually of short duration for obvious reasons if the conditions producing the initial period of high productivity be reviewed. Limited demonstration has been made at Lake Murray, a South Carolina impoundment, that planting the areas exposed by the draw-down with rapidly growing species of plants, particularly legumes, instead of permitting the natural growth of cocklebur and other weeds which generally follow the receding water, can increase the productivity of the areas so treated when the water again covers that portion of the reservoir floor. At present the expense of these operations apparently prohibits the practical application of this planting procedure in most impoundments.

However, even after the fairly constant level of low productivity (low in terms of the initial high productivity) has been established, fishing in at least some parts of most reservoirs can be improved by suitable fish management programs. Such management should look to the production of more fish food, better nesting areas and engage in careful restocking, if the water supply of the reservoir be free from pollution and does not carry too much silt. It must be remembered in this connection that fish management programs are more or less costly, especially when compared with the period of free high productivity and abundantly good fishing which naturally follows the first impounding of a new basin. Therefore, the probable success of such management procedures should be evaluated carefully in terms of local conditions at each impoundment to ascertain whether the returns will justify the expenditures.

Restocking the impoundment with fish from a hatchery frequently seems to be the reasonable solution of the poor fishing which inevitably follows the initial period of high productivity. Consequently a hatchery adjacent to the impoundment often has been suggested as part of the construction program without consideration of local conditions which may or may not be suitable for a hatchery. In this connection it should be pointed out that promiscuous stocking with miscellaneous assortments of even good species of game and food fishes, just because some of these species have proven satisfactory in other

reservoirs or lakes, should be discouraged. Local conditions often differ markedly in reservoirs in the same general district. Even under favorable conditions competing species, including many of the carnivorous game fishes, may not be able to thrive or even maintain themselves if the competition be too varied. Small fish and poor fishing may easily result if the planting be too diverse, and while the game fishes are unsuccessfully attempting to adjust themselves to this ecological unbalance the ubiquitous carp and other hardy rough fish may predominate.

Natural reproduction of the desired species can be favored in some cases by floating nests and submerged but floating brush shelters. These have been tried with varying success in several reservoirs, as Lake Tacoa in Georgia and Elephant Butte Reservoir in New Mexico. The expense of both construction and upkeep is a serious draw-back as floating nests and shelters must operate in waters subject to irregular and often extensive fluctuations of level.

Both food and nesting problems can be partly solved by the development of constant-level lateral areas through constructing small low dams only a few feet in height where possible. These dams should be near but definitely below the average expected high water levels, across the small permanent streams tributary to the impoundment. To be effective the little dams must flood areas several acres or more in extent thus creating shallows in which both emergent and submergent aquatic vegetation will become established. Before a lateral dam is constructed, the surface area of the shallows that will be produced should be ascertained as well as the minimum flow of the stream to be cut off. Should the evaporation loss from the shallows exceed the inflow from the stream during the summer months a stagnant pond will result.

When the water in the reservoir approaches the average maximal level these lateral areas will become directly continuous with the main impoundment, and fish and other animals can move in and out of the shallows over the submerged lateral dams. As the water in the main reservoir recedes, the water level in each lateral area will be maintained by the lateral dam leaving the complex of aquatic vegetation, insects and other fish food, together with the fish in the area undisturbed. Both fish and some fish food can move out into the main reservoir at any time by way of the now exposed channel of the small tributary stream which was cut off by the lateral dam. These lateral areas have made successful adjuncts to fish production in several impoundments in the Tennessee Valley but it must be remembered that should the impoundment be located in regions in which malaria is endemic, lateral shallows can become excellent breeding areas for mosquitoes as well as for fish.

The success of both floating nests and shelters and of the areas behind the lateral dams, as well as the natural reproduction of fish in other parts of the reservoir, can be increased greatly if it be possible

to adjust the draw-offs from the reservoir so as to maintain a fairly constant level in the impoundment during the breeding and nesting seasons of the desired fishes. Obviously maintenance of a stable water level is not feasible in some reservoirs. In a series of reservoirs like those along the Tennessee River in the Tennessee Valley Authority holdings, a program can be worked out, as has been done for the Wheeler Reservoir, which will time the water fluctuations so that draw-downs will be avoided during critical periods in the life cycles of the desirable game fishes.

Effects of the Impoundment upon the Parent Stream

For some distance above the impoundment the tributary stream or streams are slowed during periods of high water in the reservoir with an attendant unloading of their burdens of silt and suspensoids. During draw-downs and the periods of low water in the reservoir the tributary stream returns to normal flow rate or may actually accelerate with attendant cutting away of the silt deposited during the high water periods. Flood waters from heavy rains and sudden run-offs in the river basin, therefore, tend to project themselves more violently through the portion of the tributary river just above the impoundment during periods of low water in the reservoir. This condition favors the development of density currents and silt flows in the reservoir as previously discussed. In general, the impoundment tends to increase the instability of the tributary streams for some distance upstream from the impoundment.

Below the impoundment, particularly if the reservoir be deep, the mid-summer water temperature of the stream may be much colder than before the impoundment was created. Because of this new temperature condition trout have been planted with varying success below impoundments in several streams, including the Tennessee River below Norris Reservoir, the Colorado River below Lake Mead, and the Medina River below Lake Medina in central Texas.

However, the reduction of mid-summer stream temperature for some miles below the dam is not the only change which the impoundment makes in that part of the efferent stream. As the draw-off outlets are below the surface the water which passes through the power plant or which may be released for irrigation, or for channel depth regulation, can be drawn from the more stagnant portion of the deep water. Therefore noxious products of decomposition as well as very little dissolved oxygen may be removed from the impoundment.

The release of stagnant water from the lower layers of an impoundment can quickly produce conditions lethal for fish life some distance downstream from the dam. Particularly do lethal conditions become imminent as the undesirable water from the deeper part of the reservoir may be sent downstream at inopportune times when other factors such as high air temperature or low water stage may augment the un-

favorable action of this stagnant water from the reservoir. Catastrophes result, and one example, the killing of trout below Norris Reservoir by water drawn from the deeper part of the impoundment, has been noted recently.

The impounding of water behind a dam can, however, improve stream waters below the dam. The reservoir may act as a settling basin for much silt and other detritus which would have been moved downstream by natural river flow. Definite improvement in water conditions with respect to silt and suspensoids has been noted in the waters in the Parker Dam impoundment on the Colorado River near Needles, California, since the building of Boulder Dam across the Colorado River approximately 100 miles upstream from the Parker impoundment. Similarly, the construction of Eagle Mountain Dam on the Trinity River has reduced the silt and suspensoids in the waters of Lake Worth behind the Fort Worth Dam.

Pollution Hazards in Impounded Waters

The larger impoundments are usually lake-like masses of slack water over 30 feet in depth and often miles in extent. Therefore, the expected mid-summer stagnation of the deeper waters of such units can easily be brought to a dangerous level for fish and other aquatic life by the addition to the intake waters of small quantities of municipal sewage and industrial effluents of various sorts. Many of the existing impoundments are fed by streams whose waters have high summer temperatures and carry barely enough dissolved oxygen to maintain an average fish fauna. If the load of organic material of these streams be raised through the introduction of sewage or industrial wastes and the oxygen demand of the stream is increased thereby, stagnation develops in the waters at the upstream end of most impoundments with the onset of warm weather. The stagnant condition which moves down the reservoir as the season progresses will be both more serious and more extensive, particularly if heavy loads of silt are brought into the reservoir from time to time.

The outlet of many reservoirs is below the surface zone of the impoundment but still well above the actual bottom of the basin. If silt mixed with organic effluents of municipal or industrial origin is carried into the deeper waters of the reservoir and settles out below the level of the outlet, a pool of stagnant polluted water may develop easily. This stagnant pool can produce conditions that are hazardous to aquatic life at the time of the fall turn-over or whenever it is disturbed by the various currents due to density, draw-off, or other circumstances, which appear from time to time in many impoundments.

Less obvious than the direct pollution of the main tributary streams by organic wastes producing high oxygen demand and serious bottom conditions, is intermittent pollution from sources often located many miles from the main tributary streams. Sudden heavy rains, together

with the leaching action of melting snows or previous slow rains may flood abruptly into the main streams tributary to the impoundment large quantities of materials detrimental or even toxic to fish life. In a flowing stream fish have some chance of escape from such inrushes of noxious matter by moving out of the main stream until the high water has passed. In the impoundment the entire mass of bad water is saved and the final result will depend upon the stage of the water in the reservoir, and many other factors, if the fish escape the immediate action of the incoming slug of polluted water.

Salt waters and oil from oil-well waters, leachings from mine tailings, chat piles, extracted ore slimes which have received chemical treatments, sawdust piles, and wood mill debris, and the wash waters from creosoting plants, pulp mills and beet sugar factories, are among the many wastes that have been observed to present these intermittent pollution hazards to existing impoundments.

If silt mixed with organic effluents of municipal or industrial origin is carried into the deeper waters of the reservoir to settle below the level of the outlet, and in many reservoirs the outlet although below the surface zone of the impoundment is still well above the actual bottom of the basin, a pool of very stagnant polluted water may easily develop which can produce serious conditions for aquatic life at the time of the fall turn-over or whenever disturbed by the various currents, density, draw-off or otherwise, which appear from time to time in many impoundments.

A summary of this paper will be found in the abstract beginning on the first page.

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THE USE OF FERTILIZER FOR CONTROLLING SEVERAL SUBMERGED AQUATIC PLANTS IN PONDS[1]

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Abstract

Various submerged weeds form tangled masses of vegetation in shallow, clear-water ponds in the Southeast. It is difficult or impossible to fish in such weed-infested ponds, and the weeds protect the small fish from carnivorous species so well that overcrowding develops and stunted populations result. Hence, the control of submerged weeds is an important problem in pond management.

Commercial fertilizer has been used in the control of *Najas guadalupensis*, *Potamogeton pusillus*, *P. angustifolius*, and *Chara* sp. The following is the recommended procedure: Apply 100 pounds of 6-8-4 and 10 pounds of sodium nitrate per acre at each application, broadcasting the fertilizer over the weed-infested portion of the pond; make the first application in the winter and others at about monthly intervals until the weeds are covered with filamentous algae.

The algae shade the weeds so that they become detached and float in large decaying masses. No fertilizer should be applied while the weeds and algae are decaying actively. Most of the weeds and filamentous algae disappear by the latter part of June. As the weeds decay, nutrients are returned to the pond and the water turns green or brown due to phytoplankton. The shading effect of phytoplankton tends to prevent re-establishment of the weeds.

Chara may appear in a pond the first year it is fertilized, but usually disappears before the end of the summer and does not reappear.

Introduction

Numerous submerged aquatic plants invade clear-water ponds soon after they are constructed. In the South, these plants grow rapidly and in a short time fill shallow ponds with a tangled mass of vegetation. Such weed-infested ponds are usually poor fish ponds. It is difficult to fish in them, and the weeds often protect the small fish from carnivorous species so well that overcrowding occurs and stunted populations result.

Various methods have been tried for controlling submerged weeds in ponds. Surber (1931) used sodium arsenite for this purpose. The fact that this chemical is poisonous to man and livestock makes its general use inadvisable. In addition, it is difficult to calculate the volume of the pond and to adjust the amount of sodium arsenite so that the weeds will be killed but the fish and other animals will not be injured.

Hubbs and Eschmeyer (1938), and Martin and Uhler (1939) suggested the removal of aquatic vegetation by such mechanical means as under-water saws, aquatic mowing machines, or cables. The rapid

[1]Published with the approval of the Director.

growth of submerged weeds makes control by mechanical removal impracticable in ponds in the South. For example, *Najas guadalupensis* (Spreng.) Morong., was raked from an experimental pond[2] at weekly intervals throughout two successive summers. Despite the frequency of raking, the weed had grown almost to the surface each week and the pond was choked with it the year after raking was abandoned. Pond owners have drained their ponds hoping to destroy various aquatic plants. As will be shown later in this paper, however, draining did not control weeds in Alabama ponds.

Smith and Swingle (1941) reported the control of *Najas guadalupensis* in three ponds by the use of a complete commercial fertilizer. Application of the fertilizer in the winter and early spring induced a heavy growth of filamentous algae. These plants wrapped up the *Najas*, shaded it, and finally caused its stems to break near the base and the plant to float in large, decaying masses. After the *Najas* had decomposed, its re-establishment during the remainder of the year was prevented by the turbidity of the water caused by the resulting phytoplankton. The weed appeared in one of the ponds the following year but was destroyed again by the same treatment.

Experiments were conducted in other ponds during 1940 and 1941 to check the use of fertilizer as a method for controlling *Najas* and to determine whether this method would be effective in the control of other submerged aquatic weeds.

Experimental Methods and Results

The experiments herein reported were conducted in private ponds infested with various submerged aquatic plants. The pond owners bought and applied the fertilizer. The authors observed the ponds at intervals, directed the application of fertilizer; and kept all records. The fertilizer was broadcast over the parts of the pond dominated by the submerged weeds. The usual application of fertilizer consisted of 100 pounds of commercial 6-8-4 (N-P-K) and 10 pounds of nitrate of soda per acre, although the amount sometimes was doubled. The total amount of fertilizer per application was based on the entire area of the pond, regardless of depth or extent of weed-infestation. In the following discussion, each species of weed will be considered separately.

Najas guadalupensis (Spreng.) Morong.

Experiments dealing with the control of *Najas* were begun in three ponds in 1940 and in a fourth in 1941. One of the ponds in the 1940 experiments had an area of 19 acres and was entirely filled with *Najas* except near the dam where the water was more than 10 feet deep. Fertilization was begun the middle of March, 1940, and was continued into the early spring of 1941. Although some filamentous algae grew

[2]Unpublished data. Farm Pond Project, Alabama Agricultural Experiment Station.

on the *Najas* in the spring of 1940, fertilization evidently was undertaken too late to encourage a satisfactory development of this type of alga. Most of the filamentous algae disappeared by the middle of May, and did not reappear in any abundance during the remainder of the year.

Fertilization during 1940 encouraged the growth of phytoplankton, causing the water to appear green. A layer of desmids and diatoms, having the appearance of a flocculent precipitate, covered the leaves and stems of most of the rooted *Najas* during the months of May and June. The phytoplankton furnished sufficient shade to weaken the *Najas* in the deeper water and large masses of it had broken loose and were floating by the end of May. The *Najas* continued to break loose and about one-half of the surface of the pond was covered with floating rafts of the weed 2 weeks later. It was estimated that one-half of the pond was free of the weed in August and three-fourths of it in September. Most of the pond was free of the weed in November, the remaining *Najas* being restricted to the margins of the pond in water 5 feet deep or less and to two shallow arms. Decomposition of the floating *Najas* was extremely slow during the summer and fall; this was in contrast to its rapid decay when filamentous algae were associated with it.

Filamentous algae began to grow on the *Najas* in January 1941. The first growth of this type of algae appeared in shallow water and gradually spread into deeper water until all of the *Najas* in the pond was covered with it in April. Large rafts of floating, slowly decaying *Najas* and filamentous algae were present during April and May.

An ill-advised application of fertilizer was broadcast over the decomposing masses of *Najas* on May 29. The fertilizer caused the *Najas* and algae to decompose so rapidly that the oxygen in the water near the rafts was depleted. As the result about 200 largemouth black bass (*Huro salmoides*), weighing from 8 ounces to 7 pounds, died. A few bluegills (*Lepomis macrochirus*), golden shiners (*Notemigonus crysolencas*), and small largemouth black bass also died. Although the pond owners believed that all of the largemouth bass were lost, eight large ones were taken when one small section of the pond was seined on July 7, and subsequently others were observed feeding in various parts of the pond. These observations indicated that only the fish in the immediate vicinity of the actively decaying vegetation were killed. The unfortunate experience in this pond emphasized the fact that fertilizer must not be applied when large masses of vegetation are decomposing rapidly.

The floating *Najas* and filamentous algae continued to decompose during the early summer and disappeared before the end of July. No rooted *Najas* occurred in water more than 4 feet deep, although some was found in shallow water in August. This weed was covered with a layer of phytoplankton, lay on the bottom of the pond, and showed little evidence of growth. Apparently, nutrients were released as the

weeds decomposed; as a result, the phytoplankton kept the water green throughout the spring and summer (to the date of writing, August 6).

The second pond had an area of 15 acres. The owner had bought *Najas* and planted it, believing that it would improve fishing. The mistake was soon recognized, and after the dam broke in 1938, the pond was allowed to remain dry during the summer in an effort to destroy the weed. *Najas* reappeared in 1939, however, and fertilizer was applied during 1940 and in the early spring of 1941 to control it. The trend of events during the destruction of *Najas* was very similar to that described for the first pond. The principal differences between the results in the two experiments were: (1) Phytoplankton prevented the establishment of *Najas* in water deeper than 6 feet in the second pond in 1940; and (2) no fish were killed, since no fertilizer was applied while the weeds were decomposing rapidly.

The third pond in the 1940 series had an area of 25 acres. It was drained in October, 1939, because it was choked with weeds and overcrowded with small fish. It remained dry about 1 month and then was refilled. As in the second pond, weeds reappeared the following year. The pond was fertilized in 1940 and in the early spring of 1941. The shading effect of phytoplankton largely restricted *Najas* to water less than 6 feet deep during 1940. Filamentous algae appeared in the pond in September and covered the weed during the remainder of 1940 and the spring of 1941. The stems of the algae-covered *Najas* broke near their bases in the spring of 1941 and the margins of the pond were covered by a wide band of floating, decaying vegetation in May and early June. Most of the floating weeds disintegrated before the end of June, and all except a very narrow marginal band disappeared before the first of August. No rooted *Najas* was found on July 22. Phytoplankton imparted a deep green color to the water during 1941.

The results obtained in the three ponds were so similar that they are summarized together. Fertilization was started too late in the spring of 1940 for a heavy growth of filamentous algae to become established. Phytoplankton produced a shade sufficiently dense during the summer to cause the destruction of *Najas* in water deeper than 5 feet in the undrained pond and to prevent its establishment in deep water in two ponds that were drained prior to the initiation of fertilization. Filamentous algae began to grow in the fall or winter and completed the control of the *Najas* by the middle of the summer of 1941. Thus 1½ years were required to control *Najas* when fertilization was started too late to encourage a heavy growth of filamentous algae the first year. Decomposition of the *Najas* and filamentous algae returned nutrients to the water and very little fertilizer was required to keep the ponds green with phytoplankton during the first seven months of 1941.

A 12-acre pond had been drained three times in the past 6 years in

an effort to control submerged vegetation, including *Najas*. Weeds recurred in the pond the summer following the first and second draining. The pond was drained the third time during the winter, 1940-1941. Since draining alone had not given satisfactory weed control previously, fertilization was begun in the early spring of 1941. Filamentous algae growing on dead vegetation in the pond served as a "starter" when fertilization was undertaken. The algae grew satisfactorily and most of the *Najas* either had disappeared or occurred in floating, decaying rafts the first of July. No rooted or floating *Najas* could be found when the pond was observed July 29, indicating the complete control of this weed. Thus, *Najas* was controlled during the first year when fertilization was begun early enough in the spring for filamentous algae to cover the plants. These results are in accord with those previously reported by the authors (Smith and Swingle, 1941).

Potamogeton pusillus L.

Potamogeton pusillus formed a conspicuous element of the submerged vegetation in the pond discussed last in the preceding section. Destruction of *Potamogeton* was accomplished along with that of *Najas*. The floating rafts of decaying vegetation that were present in the pond early in July were composed of both *Potamogeton* and *Najas*. A few plants of *Potamogeton* were found in shallow water on July 29, but these were covered with phytoplankton or filamentous algae and had an unhealthy appearance.

The weed was killed in another pond, 3 acres in area, by fertilizing during the spring of 1941. As in other experiments, filamentous algae covered the weeds causing them to break off, float in large masses, and finally decay. The filamentous algae disappeared before the *Potamogeton* in this pond and the decay of the latter progressed slowly. A general observation in these studies has been that the higher plants decompose more rapidly when decaying filamentous algae are associated with them than when they are not.

Potamogeton angustifolius (of American authors)[3]

Two of the ponds in the 1940-41 experiments contained *Potamogeton angustifolius* in addition to *Najas*. The *Potamogeton* was relatively unimportant in one pond, being restricted to a few colonies in water over 10 feet deep. Following the application of fertilizer to this pond in the spring of 1940, the *Potamogeton* became covered with filamentous algae. The stems of the algae-covered *Potamogeton* broke near their bases about the middle of June. The floating plants gradually decomposed and disappeared. A few isolated stems of *Potamogeton* appeared in the pond in 1941. These plants became covered with filamentous algae and soon broke loose and decomposed.

P. angustifolius dominated the deeper part of the other pond before

[3]Identified by E. C. Ogden, University of Maine.

it was drained in 1939. Plants, which were visible in April, reached the surface of the water by the end of May 1940. The weed became covered with filamentous algae early in summer and much of it was decaying in July. Very few rooted plants remained in September and most of them were covered with filamentous algae or masses of bluegreen algae. Only two small plants of *Potamogeton* were found in the 25-acre pond when it was examined on November 10.

A number of colonies of *Potamogeton* were found in the pond on June 3, 1941. Most of the weed was covered with filamentous algae, however, when the next observation was made on June 27, and much of it had broken loose and was decomposing. Some colonies still were alive on July 22, and the filamentous algae had disappeared. Although this plant was not eradicated during 1½ years of fertilization, it was suppressed and relatively few small colonies remained.

Chara sp.

Chara grew in two of the ponds discussed in the previous sections, and in two other ponds (12 and 18 acres, respectively), the first summer that they were fertilized. It was restricted to the shallower water, mainly along the edges, where the depth was less than 5 feet. This distribution made it almost impossible to fish in much of the shallow water with hook and line. Most of the *Chara* disappeared from one of the ponds by the middle of the summer, but remained in the other three ponds throughout the first summer of fertilization. It did not reappear in any of the ponds the next year. Prolonged shading by a heavy growth of phytoplankton apparently eradicated this weed since no filamentous algae was associated with it.

Effects of Weed Control on Fish Food

The authors (Swingle and Smith, 1939) have found that the use of a complete commercial fertilizer in weedless ponds in Alabama may increase fish production 300 to 400 per cent. An explanation for the beneficial effects of fertilizer in such ponds is found in the fact that it increases the production of phytoplankton, and most fish-food organisms use these microscopic plants, either directly or indirectly, for food.

Large amounts of organic materials are made available to fish-food organisms when the higher plants decompose. Microcrustacea and aquatic insect larvae are abundant in masses of floating, decaying *Najas* and other weeds, and large and small fish congregate about these beds and feed on the associated organisms. Nutrients are liberated as the weeds decompose, and fewer than the usual number of applications of fertilizer are required to maintain a good growth of phytoplankton during the summer following the decay of the weeds. As the weeds disappear, the largemouth black bass and other carnivorous species are able to catch the small fish, and the food for these species becomes,

in effect, more abundant. As a result, all fish grow at a greatly increased rate and fishing is improved.

Discussion

Experiments dealing with the use of fertilizer for the control of submerged aquatic vegetation were conducted in five Alabama ponds, 3 to 25 acres in area, during 1940 and 1941.

The following weeds were controlled: *Najas guadalupensis, Potamogeton pusillus, Potamogeton angustifolius,* and *Chara* sp.

The effect of fertilizer in the control of submerged plants is indirect. The fertilizer induces a heavy growth of filamentous or plankton algae, or both, whose shading and possibly other effects weaken the weeds which break loose, float, and finally decompose.

Phytoplankton prevented the establishment of *Najas* in water deeper than 6 feet in two ponds and caused its destruction in the deep water of another. Control of *Najas* in the shallow areas of these ponds and of *Potamogeton pusillus* in two others was caused by filamentous algae. Phytoplankton did not prevent the establishment of *Potamogeton angustifolius* in deep water, but the control of this weed was effected by filamentous algae.

Since the control of submerged vegetation is more readily obtained when filamentous algae are present than when phytoplankton constitutes the dominant algae in the pond, it is obvious that the fertilizer should be applied at a time when it would encourage the growth of filamentous forms. Apparently, most of the species of filamentous algae associated with weed control are winter or spring annuals; hence, fertilization should be begun during the winter.

After the weeds once have been destroyed, the re-establishment of most of the species studied can be prevented by periodic fertilization to encourage the growth of phytoplankton.

The value of winter fertilization is shown by the fact that *Najas* and *Potamogeton pusillus* were controlled the first year in ponds where fertilization was begun in the winter, but 1½ years were required to obtain the same results for *Najas* when fertilization was begun too late for filamentous algae.

The presence of large masses of filamentous algae in ponds is objectionable to fishermen and health authorities. Since the species associated with weed control appear to be mainly winter annuals, they tend to disappear from the ponds in the summer and do not reappear in abundance so long as the ponds are fertilized with commercial fertilizer, unless weeds reappear.

The amount of fertilizer per acre required to control submerged aquatic vegetation depends on a number of factors, such as the species of weed and the amount of growth, the fertility of the water supplying the pond and probably the type of soil on which it is built, and the time of year that fertilization is commenced. Nutrients, released

by the decomposition of the weeds, encourage the growth of phytoplankton and reduce the amount of fertilizer needed during the remainder of the year.

Recommendations

The following procedure is recommended for controlling *Najas guadalupensis, Potamogeton pusillus,* and *P. angustifolius* by the use of fertilizer. In the southern States, the first application of fertilizer (100 pounds of 6-8-4 and 10 pounds of nitrate of soda) should be made in December or January. Subsequently, applications should be made at approximately monthly intervals until the weeds become heavily covered with filamentous algae (the algae-covered *Najas* becomes detached and floats). No fertilizer should be applied to the pond when large masses of floating, actively decaying vegetation are present. After the weeds decay and disappear, the pond should be fertilized only often enough to maintain a good growth of phytoplankton during the remainder of the season. Whenever an observer can see deeper than 18 inches into the water, an application of fertilizer should be made. Fertilizer should be applied the following winter if any weeds are found in the pond; if none are found, fertilization can be delayed until spring. In subsequent years, the pond should be fertilized to prevent re-establishment of the weeds. Even if there were no weed hazard, fertilization still would be desirable from the standpoints of high fish production and good fishing.

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THE MANAGEMENT OF PONDS WITH STUNTED FISH POPULATIONS

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ABSTRACT

The principal causes of stunted populations in impounded waters in the Southeast are: Overstocking, absence of sufficient carnivorous fish, and heavy weed growth in ponds. Recommended management practices for the correction of these conditions are: (1) weed control, (2) stocking with largemouth black bass, (3) fertilization to increase the food supply, and (4) heavy fishing to reduce the number of fish.

These measures were applied experimentally to a 3-acre pond containing a stunted population of bluegills which had been unable to produce legal-sized fish over a 10-year period. Within 6 months the pond was producing good fishing, and after 18 months, seining samples indicated that 1-year-old bluegills weighed as much as 5-year-old bluegills had at the beginning of the experiment.

The occurrence of ponds with stunted fish populations is apparently common throughout the United States. The fishing in such ponds is extremely poor as most of the fish are under legal size, or are so starved that they furnish very poor sport and are practically inedible. Fish-culturists are being called upon for advice concerning the correction of such conditions in both public and private fishing waters. One phase of the work on pond management at the Alabama Agricultural Experiment Station has dealt with methods of improving fishing in old ponds, many of which have stunted populations of fish.

There are various degrees of stunting, but for the purpose of this article stunted populations will be defined as occurring when only few of the fish present in the pond have been able to reach a legal size. The principal causes of such a condition are as follows: (1) overstocking, (2) absence of sufficient carnivorous fish, and (3) heavy weed growth in ponds. Each of these causes will be discussed briefly.

Overstocking, or the addition of more fish than a pond can support, is a very common cause of stunted populations in impounded waters. This has been due largely to lack of knowledge of how many fish a pond can support and to the widespread belief that heavy stocking can be relied upon to produce good fishing. Where a suitable carnivorous species was included in the original stocking, the overcrowded condition usually has been corrected within a period of from 3 to 6 or more years.

In ponds containing no carnivorous fish, an overcrowded and stunted condition may be expected to continue indefinitely. The most common cause of stunted populations in impounded waters in Alabama

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is the failure to stock properly such areas with a suitable species of carnivorous fish (Swingle and Smith, 1941). In the Southeast, a suitable species appears to be the largemouth black bass (*Huro salmoides* Lacépède). This species should be placed in all ponds in this section in which good fishing is desired. In the past, fish-culturists have often recommended that, in newly impounded waters, black basses should not be added until several years after the bluegills and other forage fish have been introduced. After 1 year the pond consequently is heavily overstocked and stunting begins. When the small black bass finally are added they are usually too small to begin feeding upon the stunted fish and for a considerable period must compete with them for food. Growth usually is slow and mortality high during this period. If a sufficient number of largemouth black bass has been added, the pond may eventually be balanced. However, when an insufficient number of small largemouth black bass or only a few adults have been used in stocking, results have been very unsatisfactory because the fish have always failed to reproduce successfully in ponds crowded with bluegills and other forage fishes.

A 12-acre pond was stocked in 1932 with 70 adult bluegill bream (*Lepomis macrochirus* Raf.), and 200 golden shiner minnows (*Notemigonus crysoleucas* Raf.); 1 year later 8 adult largemouth bass and 250 fingerlings were added. Fishing records were kept on the pond for a 5-year period and during which the largemouth black bass failed to reproduce successfully and did not prevent stunting in the bluegill population. During this 5-year period only four bass, weighing 3 to 5 pounds, were caught on hook and line. The dam broke in 1938 and 50 largemouth black bass weighing between 3 and 8 pounds were recovered from pools in the bottom.

In a 2-acre pond, containing a stunted population of bluegills, white crappies (*Pomoxis annularis* Raf.) and bullheads (*Ameiurus natalis* LeS.), 10 adult largemouth black bass produced only three young in 3 years, although the adults grew rapidly, gaining from 1½ pounds to 2 pounds yearly. Each year one or more females were removed, cut open, and found to be producing eggs. Similar results were secured when large fingerling largemouth black bass were added to a pond containing only a stunted bluegill population. It would appear that the eggs or newly-hatched largemouth bass were devoured by the stunted forage fish. Analyses of stomach contents of bluegills from stunted populations revealed that starving individuals will eat fish eggs of both their own and other species. This fact renders the correction of severe overcrowding more difficult.

Heavy weed growth in ponds has also been found to cause stunted fish populations. Dense weed growths hide young fish from the carnivorous species with the result that the pond soon becomes so overcrowded with small fish that satisfactory growth is impossible. Properly balanced ponds can be maintained only if the waters are sufficiently open so that the carnivorous species can find and devour most

of the small fish produced in the pond. The problem of weed control in ponds is so complex that it will be dealt with in other papers by the authors.

The simplest treatment for ponds with stunted fish populations is to drain the pond, or poison the entire fish population, and restock with the correct numbers and species of fish. These methods have been used by the authors and others (for example by Eschmeyer, 1937; Thompson and Bennett, 1939), and may be rendered necessary by the presence of obnoxious species in the pond. However, removal and destruction of the stunted population is not always possible or desirable. With an understanding of the causes of overcrowding, and the application of the proper management practices, it has been found possible to correct this condition and provide excellent fishing in such ponds within less than one year.

The following four management practices are recommended for correcting conditions that produce stunted populations in impounded waters: (1) control of dense weed growth; (2) stocking with largemouth bass if they are not already present; (3) fertilization of the pond to increase the food supply for forage fish and carnivorous fish; (4) heavy fishing to further reduce the number of small fish.

A 3-acre pond with a stunted fish population was selected to test the above practices. This pond was 10 years old and originally was stocked with bluegill bream only. It rapidly became overcrowded and the fish never reached legal size. Eight years after the original stocking, adult largemouth bass and speckled catfish were added. The largemouth bass failed to spawn successfully and failed to correct the overcrowded condition. The catfish produced some young and added to the congestion in the pond. During the 10-year period after the pond was constructed it had failed to produce legal-sized fish with the exception of one or two large largemouth black bass. Samples of the bluegills were removed and their ages and weights determined in February, 1939, at the start of the experiment. The average weights for the various ages were as follows: 4 years old, 1.3 oz.; 5 years old, 1.2 oz.; and 6 years old, 1.4 oz. No small largemouth bass could be found, but one 3-pound individual had been caught previously.

Since largemouth black bass were already present, it was decided that no more would be added, and that the only management practices needed were fertilization and heavy fishing.

The pond was fertilized during 1939 as recommended in a previous publication (Swingle and Smith, 1939). The first application was made in February, and further applications followed at approximately monthly intervals until October. By the latter part of April, the bluegills were noticeably heavier, and by June many of them had reached a weight of 4 ounces. Due to the increased food in the pond, the bluegills did not bother either the largemouth bass eggs or young with the result that large schools of young largemouth black bass were to be found in the pond for the first time. Heavy hatches of bluegills

were produced throughout the summer and were promptly consumed by the young largemouth black bass.

Fishing was begun in the pond in February, 1939, and any fish caught which was large enough to be eaten was removed from the pond. Bluegills caught during the early spring were small, averaging less than 2 ounces. By the middle of the summer, the average weight was between 3 and 4 ounces, and by fall many were caught which weighed 4 to 5 ounces. Samples were again taken in August, 1940, 18 months after the beginning of the experiment.

The average weights were as follows: 1 year old, 1.1 oz.; 2 years old, 1.6 oz.; 3 years old, 3.7 oz.; and 4 years old, 6.6 oz.

These results indicate that after 1 year of fertilization and heavy fishing, bluegills 1 year old weighed practically as much as 5-year-old bluegills at the start of the experiment. During the year, 270 pounds of bluegills, 400 pounds of speckled catfish, and 30 pounds of largemouth black bass were removed by fishing. By the application of the correct management practices a worthless pond had been changed into an excellent fish pond in less than 1 year.

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AUTUMN FOOD OF RECENTLY PLANTED YOUNG BROWN TROUT IN SMALL STREAMS OF CENTRAL NEW YORK

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ABSTRACT

Populations of young brown trout, *Salmo trutta* L., (from 66 to 111 millimeters in total length) were sampled during late August to November at known intervals after they had been planted in two streams. The stomach contents of 75 were analyzed. Two days after planting, 16 out of 26 stomachs contained some food; 82 per cent by volume was of aquatic origin. Only insects were eaten, and of these Ephemeroptera and Diptera were most important. After 16 days each of 20 stomachs contained food. Aquatic food still predominated (86 per cent), and a large part (93 per cent) was insect. Ephemeroptera and Diptera were still most important, although beetles (Coleoptera) were present to the extent of 21 per cent by volume. Earthworms, Arachnida, and isopods also were eaten. After 42 days, 10 trout were obtained. Aquatic organisms still made up a large part (79 per cent) of the stomach contents. Insects still predominated (86 per cent), and, while mayflies (Ephemeroptera) were still most important, Diptera, Orthoptera, Hemiptera and Plecoptera were well represented. The remains of a fish was found in one stomach.

In another stream with a slightly different bottom fauna, 20 out of 22 stomachs contained food 3 days after the fish had been planted. Most of the food (95 per cent) was aquatic in origin, and 95 per cent was insect. Diptera and Trichoptera were most important.

INTRODUCTION

The problem of diet transition in newly-planted trout is one which has received little attention from fishery biologists. In this study of autumn-planted brown trout, *Salmo trutta* Linnaeus, an attempt was made to observe the feeding habits, to determine to what extent a successful transition to natural food was made, and to find out what organisms were eaten most often. Two small streams were seined at intervals after they had been stocked, and a random sample of the brown trout was reserved for stomach analysis. For a few days after the fish were planted it was easy to collect large numbers, but after several weeks they were difficult to obtain by seining. Thus, the data from specimens taken in October and November are somewhat scanty.

THE STREAMS AND THEIR FISH FAUNA

The two streams studied are quite different in character, although both are in the Owasco Lake drainage, Cayuga County, New York. Deckers Brook, a tributary to Owasco Lake Inlet, 1.5 miles north of Montville, is a typical upland brook with clear, white water and a gravel and rubble bottom. The width varies from 3 feet at the nar-

rowest riffle to 15 feet at the widest pool. The depth of the pools seldom exceeds 3 feet. The flow is 3 to 5 cubic feet per second during late August and September, and the current is slow to moderate. The water temperature during the day ranges from 55° to 62° F. Individuals of fishes other than brown trout are uncommon, and the northern creek chub (*Semotilus a. atromaculatus*), and the eastern blacknose dace (*Rhinichthys a. atratulus*) are most often found.

The other stream sampled was Owasco Lake Inlet at Centerville. This is a larger stream with a flow of 10 to 25 cubic feet per second during August and September. The water is white and usually somewhat turbid. This turbidity is imparted by fine particles from clay banks which are frequently found for several miles upstream. The pools vary from 10 to 30 feet in width and up to 6 feet in depth. The riffles are about half as wide and are short. The bottom is similar to that of Deckers Brook and consists mostly of rubble and gravel with a little sand and silt. The daily water temperatures varied from 52° to 66° F. during late August, September and early October. A large fish population was present at Centerville. The most common species were the common sucker (*Catostomus c. commersonnii*), eastern sturgeon sucker (*Catostomus c. catostomus*), longnose dace (*Rhinichthys cataractae*), eastern blacknose dace (*Rhinichthys a. atratulus*), eastern common shiner (*Notropis c. cornutus*), fallfish (*Leucosomus corporalis*), northern creek chub (*Semotilus a. atromaculatus*), bluntnose minnow (*Hyborhynchus notatus*), eastern silvery minnow (*Hybognathus nuchalis regius*), barred fantail darter (*Catonotus f. flabellaris*), and rainbow trout (*Salmo gairdnerii irideus*).

Owasco Inlet differs from Deckers Brook mainly in that it is practically always turbid, has a bottom fauna in which more fly and midge larvae (Diptera) and caddisfly larvae (Trichoptera) are found, and where mayfly nymphs (Ephemeroptera) and stonefly nymphs (Plecoptera) are relatively scarce; and it has relatively a large fish fauna, both in individuals and species. In point of abundance the bottom fauna of Deckers Brook is rated as average, while that of Owasco Inlet is good.

When first observed in Deckers Brook 2 days after they had been planted, the young brown trout were easily recognized as hatchery fish by their behavior. Large groups of up to 300 individuals were seen in the larger pools near bridges. They were in rather dense schools and were facing toward the current much as they behave in a hatchery pond. A few individuals were noticed to leave the typical positions in the school and to nose about the bottom as if to feed. They were dark colored, and, when removed from the water and examined, they lacked the red spots on the sides and the orange adipose fin which are characteristic of wild brown trout of this size (3 to 4 inches in total length). The stocked brown trout also showed abnormal fin development. The dorsal fin was short and somewhat deformed and the pectoral fins were also relatively short.

On September 9, 16 days after planting, these young brown trout had not yet developed the red spots on the sides, nor was the adipose fin orange in color. On October 5, 42 days after liberation, a few red spots had appeared on the sides of some, and on a few the adipose fin had an orange tinge. By October 5 young brown trout were very hard to find in either stream, indicating that a considerable mortality had occurred, or more probably, that the fish had become more evenly distributed throughout the stream and had learned to take advantage of the available natural cover.

Food of Brown Trout

Each brown trout was treated as a unit in the analysis of its stomach contents. The organisms were identified, counted, and the volume of each type was estimated. Time did not permit a thorough quantitative study of the relative abundance of the major types of trout food. No attempt has been made to summarize the large quantity of literature available on the food of brown trout since such would hardly be pertinent to this study. Lord (1935, p. 28) studied the food of 78 yearling brook trout which were marked and liberated on August 18 and were captured from August 19 to September 5. The number of empty stomachs was not reported, but 79 per cent of the contents was aquatic in origin. Of this aquatic food, mayflies composed 49 per cent; caddisflies, 34 per cent; and 17 per cent was miscellaneous insects. The 21 per cent of terrestrial food was chiefly beetles and flies. He also studied the stomachs of 49 yearling rainbow trout which were liberated on September 2 and caught from September 4 to 25. Aquatic insects occurred as 95 per cent, terrestrial as 5 per cent. The aquatic insects were divided as follows: Mayfly nymphs, 65 per cent; caddisfly larvae, 16 per cent; stonefly nymphs, 11 per cent; Diptera, 4 per cent; and miscellaneous, 4 per cent. The terrestrial food was mostly beetles and flies.

An analysis of the 46 stomach contents from Deckers Brook is presented in Table 1. A considerable number of stomachs (10 out of 26) of those trout taken 2 days after they had been planted were empty. Since the intestines of those fish whose stomachs were empty also failed to reveal traces of food, it may be inferred that some young brown trout are unable in this length of time, either to make the transition to the available food, or to compete successfully when large numbers are planted in close proximity. A large part of the contents (82 per cent) of the 16 stomachs containing food was of aquatic origin. This might be expected especially when considered in the light of hatchery feeding methods where the food settles to the bottom of the tank. An added fact of interest is that 100 per cent of the food, after 2 days, consisted of insect forms, with Diptera and Ephemeroptera appearing most often.

After 16 days in Deckers Brook all stocked brown trout which were

Table 1.—The food of 46 recently planted brown trout from Deckers Brook, 1.5 miles north of Montville, Cayuga County, New York

Date collected	August 26			September 9			October 5			Total		
Days in stream (stocked Aug. 24, 1941)	2			16			42			....		
Mean total length in millimeters	85.0			82.1			78.4			82.1		
Range of total length in millimeters	70-100			66-96			68-87			66-100		
Stomachs with food	16			20			10			46		
Stomachs empty	10			0			0			10		
Food item	A[1]	B[2]	C[3]	A	B	C	A	B	C	A	B	C
Aquatic origin	....	14	82	....	20	86	....	10	79	....	34	83
Terrestrial origin	....	5	18	....	8	14	....	4	21	....	17	17
Earthworms (Chaetopoda)	....	....	....	0.1	1	5	....	....	....	+	1	2
Scuds (Isopoda)	....	....	....	0.1	2	1	....	....	....	+	2	*
Insects	....	16	100	....	20	93	....	10	86	....	46	94
Spring-tails (Collembola)	....	....	....	0.1	3	2	....	....	....	+	3	1
Grasshoppers, crickets (Orthoptera)	....	....	....	....	....	....	0.1	1	9	+	1	2
Sialids (Neuroptera)	....	....	....	....	....	....	0.1	1	1	+	1	*
Mayflies (Ephemeroptera)	1.2	7	33	1.4	10	16	2.1	6	22	1.5	23	23
Dragonflies, damselflies, (Odonata)	0.1	2	3	0.2	3	5	....	....	....	0.1	5	4
Stoneflies (Plecoptera)	0.1	1	1	0.2	2	1	0.6	3	8	0.2	6	2
Bugs (Hemiptera)	0.1	2	4	0.3	4	2	0.8	3	10	0.3	9	5
Beetles (Coleoptera)	0.1	2	8	0.6	8	21	1.3	2	2	0.4	12	12
Caddis flies (Trichoptera)	0.1	1	1	0.5	5	6	0.9	4	11	0.4	10	5
Flies (Diptera)	0.6	5	16	2.8	15	21	2.7	7	7	2.0	27	16
Bees, ants (Hymenoptera)	....	....	....	0.1	2	1	0.1	1	*	0.1	3	*
Insect remains	....	9	34	....	19	18	....	8	16	....	36	23
Spiders (Arachnida)	....	....	....	0.2	3	1	1.4	2	11	0.2	5	3
Fish	....	....	....	....	....	....	0.1	1	3	+	1	*

[1]Average number of food items per stomach.
[2]Number of stomachs containing food item.
[3]Percentage by volume (those marked with an asterisk contained less than one-half of 1 per cent).
+Trace.

Table 2.—The food of 29 recently planted young brown trout from Owasco Lake Inlet at Centerville, Cayuga County, New York

Date collected	August 29			Oct. 5; Nov. 1 and 22			Total		
Days in stream (stocked August 24, 1941)	3			....			....		
Mean total length in millimeters	85.7			84.0			85.1		
Range of total length in millimeters	70-111			71-97			70-111		
Stomachs with food	20			9			29		
Stomachs empty	2			0			2		
Food item	A[1]	B[2]	C[3]	A	B	C	A	B	C
Aquatic origin	....	20	95	....	8	72	....	28	88
Terrestrial origin	....	5	5	....	6	28	....	11	12
Plants	....	1	*	....	3	2	....	4	1
Earthworms (Chaetopoda)	0.1	1	4	....	....	....	+	1	2
Millipedes (Diplopoda)	....	....	....	0.1	1	7	+	1	2
Insects	....	20	95	....	9	86	....	29	92
Mayflies (Ephemeroptera)	0.4	5	8	0.4	1	3	0.4	6	6
Dragonflies, damselflies (Odonata)	....	....	....	0.1	1	1	+	1	*
Stoneflies (Plecoptera)	0.2	4	6	....	....	....	0.1	4	4
Bugs (Hemiptera)	0.1	1	4	0.3	2	2	0.1	3	4
Beetles (Coleoptera)	0.2	2	6	0.7	6	22	0.3	8	11
Caddis flies (Trichoptera)	1.8	14	29	1.6	7	27	1.7	21	28
Moths, butterflies (Lepidoptera)	....	....	....	0.1	1	1	+	1	*
Flies (Diptera)	3.1	18	30	2.0	6	20	2.8	24	27
Bees, ants (Hymenoptera)	0.1	1	1	....	....	....	+	1	1
Insect remains	....	10	11	....	6	11	....	16	11
Spiders (Arachnida)	0.1	1	1	0.1	1	1	0.1	2	1
Snails (Gasteropoda)	....	....	....	0.2	1	4	0.1	1	2

[1]Average number of food items per stomach.
[2]Number of stomachs containing food item.
[3]Percentage by volume (those marked with an asterisk contained less than one-half of 1 per cent).
+Trace.

collected contained food, 86 per cent of which was aquatic in origin. Insects still stood relatively high (93 per cent), but Arachnida, isopods and earthworms also were eaten. Although Diptera and Ephemeroptera were most important, Coleoptera were eaten in considerable quantities. After 42 days in the stream the food was 79 per cent aquatic in origin, and 86 per cent was insect. While Ephemeroptera were quite important among the insects, Diptera had fallen off somewhat, and four other insect orders: Trichoptera, Plecoptera, Hemiptera, and Orthoptera were of considerable importance. The suggestion may be made that the young trout were becoming more adept at hunting under stones for Trichoptera and Plecoptera, while most of the Hemiptera and Orthoptera were taken from the surface. No pronounced fluctuations in number of available insects were observed through an examination of the bottom during the period of this study, although the use of quantitative methods might have shown otherwise. Eleven per cent of the volume was Arachnida, and the remains of a single fish was found in one stomach. A summary of the stomach contents of 46 brown trout from Deckers Brook (Table 1) indicates that the food was largely aquatic in origin (83 per cent). Insects made up the bulk of the food, and the most important orders were Ephemeroptera, Diptera, and Coleoptera.

After 3 days in Owasco Inlet (Table 2) only two out of 22 (or 9 per cent) of the brown trout stomachs were empty. As mentioned above, after 2 days in Deckers Brook 38 per cent were empty. The difference between the feeding activities in the two streams could hardly have been due to chance and is positively correlated with the relative abundance of available bottom food in the two situations. In Owasco Inlet 95 per cent of the stomach contents was aquatic in origin, and 95 per cent was insect food. Diptera and Trichoptera (30 and 29 per cent) were most important, and few Ephemeroptera (8 per cent) were eaten. Comparatively few Ephemeroptera were present here, while in Deckers Brook they were common and made up 33 per cent of the food after the trout were in the stream 2 days. Only nine brown trout were obtained from Owasco Inlet during October and November. Trichoptera and Diptera were still important items, and Coleoptera occurred as 22 per cent of the stomach contents. Ephemeroptera were present as 3 per cent by volume.

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A SUDDEN MORTALITY OF FISHES ACCOMPANYING A SUPERSATURATION OF OXYGEN IN LAKE WAUBESA, WISCONSIN

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ABSTRACT

A heavy loss of fish occurred during April 1940, in the south end of Lake Waubesa, Wisconsin, and in the Yahara River below the lake. The fish affected were mainly black crappies, although bluegills, northern pike, yellow pikeperch, common suckers, and carp, were killed to a lesser extent. A heavy algal bloom composed principally of *Chlamydomonas* was concentrated in the area of fish loss and was accompanied by an extremely high (30-32 p.p.m.) oxygen content in the surface water.

Characteristic lesions were present in the fish and consisted primarily of gas emboli in the gill capillaries and gas bubbles in the subcutaneous tissues. Death of the fish was attributed to the blocking of the circulation through the gills by the gas bubbles with consequent respiratory failure. A suggestion is made that oxygen was the gas forming the bubbles.

INTRODUCTION

During the latter part of April 1940, a heavy loss of fish occurred in Lake Waubesa, Wisconsin. No estimate was made of the fish that died but at least several thousand were observed. Conversation with people familiar with the lake indicated that minor losses occurred every spring but never reached as serious proportions as in 1940. Since the loss was from a rather unusual cause it was felt that a description would be of value.

FISH AFFECTED

Black crappies (*Pomoxis nigro-maculatus*) were the predominate fish affected. However, other fish such as bluegills (*Lepomis macrochirus*), northern pike (*Esox lucius*), yellow pikeperch (*Stizostedion v. vitreum*), suckers (*Catostomus commersonnii*), and even an occasional carp (*Cyprinus carpio*), were found dead or dying. Nearly all of the dead crappies were of the 1936 year class, that is, fish hatched in 1936. Very few crappies of other ages were noted. In general all fish found were large mature adults. No small or young fish of any species were observed.

SYMPTOMS

The distressed fish were observed only in the last stages of the disease shortly before death so that the early symptoms could not be recorded. In the final stages the fish showed partial to complete loss of

equilibrium, and passed gradually into a coma or stupor which grew deeper until death.

General Appearance and Pathology

The general appearance of the fish was normal except for the presence of small gas bubbles, visible to the naked eye, under the scales, skin, and between the rays of the fins. This was the most prominent pathological manifestation. The bubbles gave the fins, and occasionally the skin, the appearance of having a large number of blisters and were

Figure 1.—Portion of yellow pikeperch showing gas bubbles in scale pockets and between rays of dorsal and anal fins

present on nearly all the fish observed. The condition is illustrated in Figure 1 which shows the general appearance of the skin and anal fin of a yellow pikeperch found dead in the lake. The gas bubbles may be seen between the fin rays very distinctly, especially in the anal fin. Certain of the scales have been raised by the formation of bubbles in the scale pockets.

The gills also were damaged severely, moreso than other parts of the body. The primary cause of the damage was the presence of gas emboli in the capillaries of the gill filaments. Most of the filaments examined contained gas emboli of such a size that they completely blocked the flow of blood through the capillaries. Figure 2 shows a gill filament in which the gas bubbles can be seen blocking the capillary. The obstruction of blood circulation in the capillaries resulted eventually in the death of the filament with consequent degenerative

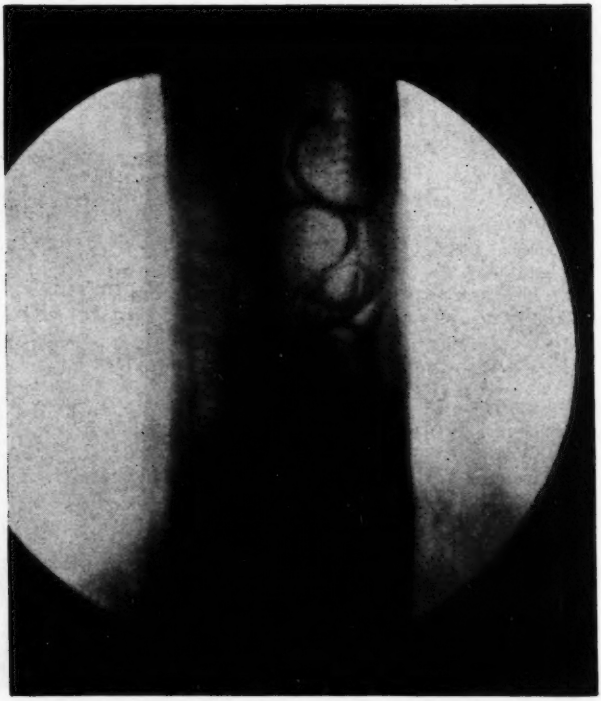

Figure 2.—Gill filament of yellow pikeperch showing gas bubbles in capillary

changes. In many of the fish examined large areas of the gills were necrotic and overgrown with fungus, in others the gill tissue had sloughed away leaving only the supporting strip of cartilage. Blood clots were seen between the lamellae of many of the gill filaments. Occasionally an eye would be damaged by the formation of bubbles within the eyeball.

Water Conditions

At the time of examination the water along the entire south (windward) shore of the lake had a greenish appearance due to an algal bloom, and a thick layer of algae was present in a band about 10 feet wide along the shore line. Upon identification the major part of the algal layer was found to consist almost entirely of *Chlamydomonas,* with small amounts of Protozoa, diatoms, desmids, and filamentous algae constituting the remainder.

Analyses of the lake water revealed an extremely high dissolved-oxygen content and an unbalanced condition of the carbonate-bicarbonate content. The results of the analyses are presented in Table 1.

Table 1.—Results of analyses of oxygen and carbonate-bicarbonate content of Lake Waubesa water at time of the heavy fish loss

Station	Depth (feet)	Dissolved oxygen (p.p.m.)	Percentage saturation	Bicarbonates (p.p.m.)	Carbonates (p.p.m.)
20 feet offshore....	1	30.0	306	57.0	88.0
150 feet offshore..	1	32.1	327	.....	.....
150 feet offshore..	12	16.8	171	.....	.....

The large quantities of *Chlamydomonas* in the water undoubtedly account for the extreme unbalance of the dissolved gases. The weather preceding the outbreak of the epizootic had been clear and bright thus furnishing sufficient light for photosynthesis to proceed at a rapid rate. The high preponderance of carbonates in the water was probably due to the breaking down of the bicarbonates by the algae once the free carbon dioxide was exhausted. The supersaturation of oxygen was also present in the river below Lake Waubesa. Fish losses occurred in the river but not of the magnitude of those in Lake Waubesa.

Diagnosis and Cause of Death

Death of the fish apparently was caused by the formation of gas emboli in the gill capillaries and possibly in other critical areas of the body such as the heart chambers. The presence of gas bubbles in the gill capillaries of such a size as to prevent circulation would lead to necrosis of the gills and eventual death due to respiratory failure.

The process through which the gas emboli appeared in the capillaries

and the tissues can be only conjectured. Fish living for any length of time in water supersaturated with oxygen undoubtedly would soon have their blood and tissues likewise supersaturated with oxygen. A number of factors might have caused the release of oxygen bubbles into the blood stream or tissues. A slight rise in the body temperature of the fish due to increased activity might have been the direct agent since oxygen solubilities decrease with increasing temperatures. Again the water may have lost oxygen to the atmosphere due to wind agitation following a calm and a rise in temperature, thus rendering the fish blood and tissues supersaturated with respect to the water. Both of the above hypotheses predicate that the change occurred so rapidly that the oxygen escaped into the blood or tissues of the fish rather than being slowly diffused back through the gills into the water.

Examination of the literature indicates that the death of fish because of oxygen emboli in the capillaries is not an unique phenomenon. Schaperclaus (1933, p. 252) recorded a disease of young trout (Gasblasenkrankheit) in which gas bubbles appear under the skin especially on the head and gills. Plehn (1924) attributed the "gas bubble disease" to the supersaturation of the water by oxygen due to a rich plant growth.

Haempel (1928) discussed in some detail the effects of high oxygen concentrations on fish especially under conditions of artificial supersaturation with oxygen. He indicated that salmonid fishes exposed to high oxygen concentrations develop at first a marked uneasiness and dyspnoea followed by a loss of equilibrium and finally a stupor or oxygen narcosis. With further continuous supersaturation of the waters, the fish died. He recorded such pathological symptoms as opaqueness of the cornea, exophthalmia, and release of gas bubbles from the capillaries. Haempel's paper indicated that 2 or 3-year-old goldfish and the Zander (*Lucioperca sandra*, the European species of yellow pikeperch) do not succumb to the above conditions as easily as do the young fish, but do show symptoms of irritability.

Marsh and Gorham (1905) made a detailed study of a gas disease in fishes in which they described symptoms, pathology and etiology of this condition. The symptoms and pathology are in general the same as those described in this study and by Haempel and Schaperclaus. However, the disease as described by Marsh and Gorham accompanied an excess of nitrogen in the water and analyses of the gas in the skin blebs and heart chamber indicated that nitrogen was the gas responsible. Those authors discussed the possible role of oxygen in producing the gas disease but had no instances where oxygen was responsible.

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RELATIONSHIP BETWEEN THE PLANTINGS OF FRY AND PRODUCTION OF WHITEFISH IN LAKE ERIE

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ABSTRACT

An attempt was made to substantiate the repeated assertions of the commercial fishermen on the Great Lakes and of others that there was a direct causal relationship between the plantings of whitefish fry and subsequent catch. The records of whitefish fry plantings in Lake Erie during the years, 1920-1937, were correlated with those of catch during the period, 1923-1940. No causal relationship could be demonstrated between the two sets of data. Whitefish production in Lake Erie is not dependent on or noticeably affected by the planting of fry.

The question concerning the artificial propagation of fish in the Great Lakes is still a lively subject of debate. Those who favor artificial propagation almost invariably base their stand on the conviction that the planting of fry in the past has maintained the fisheries or has increased production. They believe that there was a direct relationship between fry planting and subsequent production. Commercial fishermen have testified repeatedly that when fry were planted in their waters their catches increased a few years later. From none of the fishermen who claimed to have experienced these increased yields have I been able to obtain statistics to substantiate their assertions. The considerable increase in the production of whitefish (*Coregonus clupeaformis*) in Lake Erie in 1939 and 1940 gave new impetus to the claim that the hatcheries are really effective.

If these fishermen's contentions are correct, we should be able to show a correlation between the annual number of fry planted in a lake and the catch in subsequent years. Hile (1937) and others (see Van Oosten, 1937) attempted to show such correlations in the yellow pikeperch (*Stizostedion v. vitreum*) and the whitefish, but without success.

To determine the relationship between the number of whitefish fry planted in Lake Erie and the catch in subsequent years, data have been compiled (Table 1) covering a period of 21 years (1920-1940). The table gives for each year the number of fry planted in the United States and Canadian waters of the lake and the catch of whitefish from this lake 3 years later. The data are shown graphically in Figure 1. The records were obtained from private communications or publications of the several conservation departments, the former Bureau of Fisheries, the Fish and Wildlife Service, and the Province of Ontario. The interval of 3 years was selected since our data indicate that 3-year-old fish (in fourth summer of life) comprise, on the average,

Table 1.—Relationship between the plantings of fry and the production of whitefish in Lake Erie. The numbers of fry are expressed in thousands, that is, the last three zeros are omitted. The years of planting and of catch are separated by a 3-year interval

Number of fry planted				Catch in pounds			
Year	United States	Canada	Total	Year	United States	Canada	Total
1920	384,990	31,112	416,102	1923	488,577	536,123	1,024,700
1921	517,712	40,000	557,712	1924	330,791	580,356	911,147
1922	538,820	74,000	612,820	1925	583,000	1,033,077	1,616,077
1923	332,790	87,500	420,290	1926	961,157	868,137	1,829,294
1924	384,538	115,469	500,007	1927	624,445	747,964	1,372,409
1925	195,480	37,550	233,030	1928	974,469	987,889	1,962,358
1926	258,319	81,970	340,289	1929	1,079,061	1,267,485	2,346,546
1927	76,380	75,895	152,275	1930	1,521,532	1,087,689	2,609,221
1928	162,400	44,100	206,500	1931	1,272,869	1,106,354	2,379,223
1929	120,141	34,505	154,646	1932	1,168,570	912,160	2,080,730
1930	137,700	32,417	170,117	1933	997,140	710,039	1,707,179
1931	141,220	50,084	191,304	1934	778,581	915,934	1,694,515
1932	147,400	77,087	224,487	1935	994,875	1,190,121	2,184,996
1933	356,904	71,920	428,824	1936	1,158,368	1,767,741	2,926,109
1934	69,290	67,242	136,532	1937	647,451	1,401,016	2,048,467
1935	273,500	96,620	370,120	1938	910,898	1,001,788	1,912,686
1936	191,580	44,942	236,522	1939	2,098,088	2,312,200	4,410,288
1937	83,500	131,160	214,660	1940	2,642,685	3,136,000	5,778,685
1938	72,800	139,000	211,800	1941	.....	.....	.....
1939	.....	[1] 50,000	50,000	1942	.....	.....	.....
1940	122,600	83,588	206,188	1943	.....	.....	.....
Average	217,527	69,817	287,344	Average	1,068,475	1,197,893	2,266,368

[1]The water supply of both the State and Federal hatcheries at Put-in-Bay failed and as a consequence the eggs were returned to the lake on December 29, 1938.

approximately 60 per cent of the number (somewhat less of the weight) of legal whitefish taken by the commercial fishermen in the United States waters of Lake Erie. The IV-group ranked second in abundance. Very few whitefish older than the IV-group or younger than the III-group normally occur in the commercial catch.

No attempt was made to ascertain whether the plantings of fry had local effects on the fishery since all available evidence indicates that the whitefish move from one end of Lake Erie to the other and from one side of the international boundary to the other, and that the population is homogeneous throughout the lake. It is to be expected, therefore, that whitefish planted in a certain area may, if they survive to catchable size, later be taken anywhere in the lake. The only logical and valid method of approach, then, is to obtain a correlation between all the fry planted in the lake and the total annual production.

Incidentally, it may also be explained that this study attempts only to correlate plantings of fry with the annual yield of whitefish, not with its actual abundance, since the primary objective is to substantiate if possible the commercial fishermen's contention that plantings and catch are causally related. Undoubtedly the statistics of production of the whitefish in Lake Erie reflect in general the true abundance of the species, and any correlation established between plantings and catch may also be assumed to exist between plantings and abundance.

If the planting of fry was effective and a dominant factor in maintaining the whitefish catch in the past, it may be assumed that a

change in the size of the plantings would be reflected in a corresponding change in the size of the catch 3 years later. If such a relationship existed the two curves of Figure 1 should follow each other and as a rule be on the same side of the heavy horizontal line that represents the averages of both the catch and the number of fry planted during the period, 1920-1940. They, however, do not conform. In 11 different years the two curves go in opposite directions, and in 6 years in the same direction. Further, the large plantings (1920-1924) at the beginning of the period, which were all above the average, were followed by relatively low yields, that were all below the average for the period, and the small plantings after 1924 were followed by high yields. This apparent inverse relationship is substantiated by a statistical analysis which showed a negative correlation of —0.38 between the two sets of data (significant coefficient =0.47). It is obvious, therefore, that the total catch of whitefish in Lake Erie in any one year was not causally related to the number of fry planted 3 years earlier in the lake.

The statistics for 1939 and 1940 (Table 1) support the fishermen's testimony that the productions for these years were exceptionally high. If artificial propagation was responsible for these high yields then the

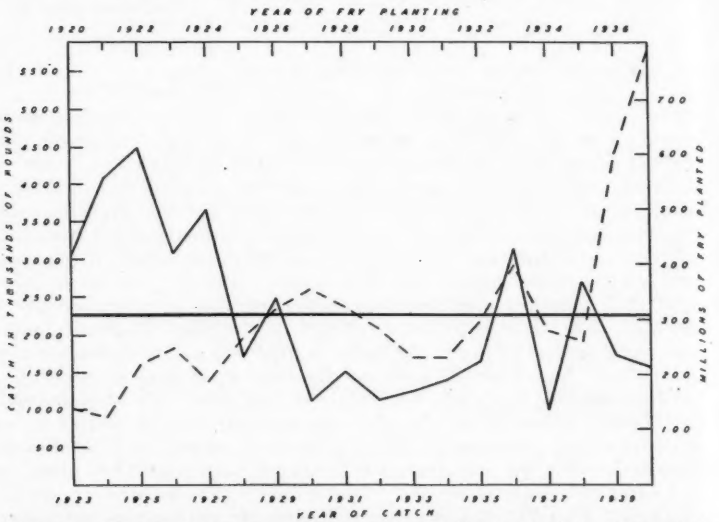

Figure 1.—Relationship between plantings of whitefish fry in Lake Erie and the total catch 3 years later. Solid curve = fry plantings; broken curve = production. The heavy horizontal line cutting across the curves represents the averages of both catch and the number of fry planted during the period, 1920-1940, and the curves indicate the deviations from average.

number of fry planted in 1936 and 1937 must have been large. The table, however, reveals that the quantity planted was below average. It appears, therefore, that the large yields of whitefish in 1939 and 1940 had no causal relationship with the quantity of fry planted 3 and 4 years earlier.

Since the IV-group whitefish usually ranked second in abundance in the commercial catch, the plantings of fry were also correlated with the catch taken 4 years later. Again a negative coefficient of correlation (—0.20) was obtained (significant coefficient =0.48). Further, the average percentages contributed to the annual catch by both the III- and IV-group fish were computed and the total number of fry planted was correlated with the computed United States yield of the 3- and 4-year-old fish in the production 3 and 4 years later. Once more a negative correlation (—0.46) resulted (significant coefficient =0.48).

We must conclude, then, that the evidence presented indicates that the planting of whitefish fry in Lake Erie during the period, 1920-1937, had no noticeable effect on the whitefish production in the years 1923-1940. The exceptionally high yields of 1939 and 1940 cannot be attributed to large plantings.

I am greatly indebted to Dr. Frank W. Jobes for valuable assistance rendered in compiling the statistical data.

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A METHOD OF MEASURING THE NUMBER OF ECTOPARASITES INFESTING HATCHERY FISH, WITH PARTICULAR APPLICATION TO *GYRODACTYLUS*

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ABSTRACT

A quantitative method is presented for estimating the intensity of infestation of the ectoparasite *Gyrodactylus* on goldfish. When infested fish are immersed in solutions of cresol the *Gyrodactylus* leave the fish and drift about in the liquid. The number of organisms in the solution may then be counted by standard methods. A series of experiments was performed to determine the variability in counts of parasites as it might be influenced by the use of several different fish, by different workers making the counts, by variations in the time interval between the immersion and counting, and by the concentration of the cresol. From experimental evidence obtained, it was concluded that considerable variability was associated with the counts made from different fish. Counts made by different workers and counts made after various immersion times, did not vary significantly. Concentrations of 1:4,000 to 1:6,666 (parts cresol: parts water) appeared to be satisfactory for use with *Gyrodactylus*. The method described is suitable for use with modern experimental designs and provides a quantitative "yardstick" for judging the effectiveness of various treatments for controlling ectoparasites on fish.

INTRODUCTION

During the past decade a large number of treatments have been proposed for the control of ectoparasites of fish in trout hatcheries. Such control measures usually involve two important considerations: First the selection of a certain drug (salt, formalin, etc.) for removing the parasites; and second, the method of applying the drug to the fish (dipping, the use of recirculation tanks, etc.). Although it is quite apparent that many of the treatments recommended accomplish to some degree their purpose of removing the organisms from the fish, very little may be said as to which drugs or which methods of application produce the best results. Thus there is much controversy among fish-culturists as to the usefulness of the various treatments.

This conflicting situation seems to arise from a lack of suitable methods of testing the alternative treatments experimentally. The present-day systems of testing apparently cannot provide the information necessary for scientific comparisons. What seems to be needed is a technique for estimating the intensity of infestation, the number of parasites per fish, under various conditions. With such a technique the advantages of modern experimental designs could be employed to provide valid tests of the relative merits of the various drugs and methods of applying them.

A search of the literature has revealed one possible method of esti-

mating the number of parasites per fish, namely the method used by Fish and Burrows (1940). This method consists of making counts of the parasites removed from a fish by a centrifuge. To date these authors have not reported on the standardization of their technique or used it in connection with modern experimental designs; but judging from data they have published from individual experiments it seems to be quite sensitive and might be used in the standard randomized block design (Fisher, 1937).

A second possible method has been suggested which utilizes certain properties of the drug cresol. It has been observed (unpublished data of G. C. Embody) that when infested fish are placed in solutions of cresol great numbers of the ectoparasites leave the fish and drift about in the solution. Thus it is possible that cresol solutions might be used to remove parasites from infested fish in such a manner that a count of the number per fish might be obtained.

Methods of counting organisms in solutions have been developed by bacteriologists and plankton investigators. The methods fall into two general groups. First, there are total counts where the organisms are concentrated into a small volume by means of a centrifuge and then placed on a microscope slide. Total counts are, therefore, very precise but require considerable time, expensive equipment, and manipulative skill to perform. Second, there are counts where a specified volume of the original solution is sampled, placed on a special microscope slide and the total number obtained by multiplying the count on the slide by a factor which is based on the proportion sampled. Sample counts can be made very rapidly but such determinations are subject to random samplying variations.

When the mean numbers of parasites per fish are estimated from two or more groups of fish for the purpose of testing whether differences exist, it is necessary that the variability of infestation within the groups of fish be measured, since the within-group variation is the criterion for making statistical tests with F or t (Snedecor, 1940). Both the centrifuge and sampling methods, when used with a standard experimental design, will provide a means of estimating the within-group variation. The fact that random sampling variation exists does not prevent the use of the sampling method because in properly designed experiments this factor can be controlled. In the present study it was decided, therefore, that the sampling method could be used.

Statement of the Problems

The use of cresol to estimate the number of parasites on fish involves two operations which must be standardized. First, the fish must be held in a solution of the proper strength for a sufficient length of time to remove the parasites. Second, the number of parasites in the solution must be estimated.

To measure the relative intensity of infestation for testing parasite control treatments it is not a necessary condition that all of the organisms be removed from the fish. The precision of the test, however, is greater when a high percentage of the organisms is removed. Hence any concentration and immersion time which removes parasites would provide a valid test, but the concentrations and immersion times which removed the larger number of organisms would probably provide the *better* test.

A group of several hundred goldfish (*Carassius auratus*) was available for the study of fish parasites. The fish were heavily infested with the protozoan *Gyrodactylus*, a parasite which is commonly found on trout in hatcheries. It was decided, therefore, that for the development of the method, the tests would be made using goldfish as the host and *Gyrodactylus* as the parasite.

Several preliminary experiments were conducted to develop a standard technique for testing the relative value of different concentrations for removing parasites from the fish. Each experiment consisted of placing a goldfish in a particular concentration of cresol for 5 minutes and then transfering it to another solution of the same concentration for 5 minutes more. By estimating the parasites in both solutions the number of organisms removed in 5 and 10 minutes could be found. From preliminary experiments it was found that with concentrations between the range of 1:4,000 (parts cresol: parts water) to 1:20,000, approximately 95 per cent of the organisms removed in 10 minutes had left the fish in the first 5 minutes of immersion. Thus it was decided that the efficiency of concentrations in the range of 1:4,000 to 1:20,000 could be judged according to the percentage of *Gyrodactylus* removed in 5 minutes when compared with the number removed by immersion for 10 minutes.

Before the method could be used to estimate the intensity of infestation of parasites on a group of fish some of the more important factors which might influence the use of the drug had to be studied. The results of preliminary experiments have indicated that there are at least three important factors which must be considered.

First, in a group of infested fish there is likely to be a considerable variation in the numbers of parasites on each fish. Such heterogeneity would be of great importance in determining the number of individuals that would have to be used to sample a large group of fish. As a step in this direction a test should be included to determine the relative variability in the numbers of *Gyrodactylus* on different fish of the same group.

Second, the question may be asked as to the extent to which the method may be used by different workers. Hence it was decided that a test should be made to determine the variability in results when several workers used the same material.

Third, there is the possibility that the time interval between the immersion of the fish and the counting of the parasites might influence

the results. For example some of the *Gyrodactylus* after remaining some time in the solution might disintegrate or become attached to the walls of the container. In such an instance counts made immediately after immersion would tend to be higher than counts made some time after immersion. It was decided, therefore, that a test of the influence of time on the counts should be considered.

There are, therefore, four distinct sub-problems concerned with the development and utilization of the method. The general statement of the sub-problems is as follows:

1. Is a given population of fish homogeneous with respect to the extent of the *Gyrodactylus* population? In other words, do the numbers of parasites on various fish vary by an amount greater than the random sampling variation of the counting method?
2. Do counts made by various workers vary significantly?
3. Do variations in the time interval between immersion and counting influence the estimates of parasites?
4. Do variations in the concentration of cresol in the range from 1:4,000 to 1:20,000 influence the proportion of *Gyrodactylus* removed from goldfish?

The Possible Solution

Each of the above problems involves the influence of some factor deemed to be important in the operation of the method. The generalized null hypothesis (Fisher, 1937) provides a possible solution to the problems and may be stated thus: If a series of independent comparisons is set up in which goldfish are placed in solutions of cresol and counts are made of the *Gyrodactylus* under conditions which are varied with respect to the goldfish used, the workers making the counts, the time interval between immersion and counting, and the concentration of the cresol, then variations will be found in the counts which are associated with the factors varied, but such variations will constitute a single normally distributed set. If the null hypothesis is refuted by the evidence of any of the comparisons, then the variations involved with the particular comparisons will be judged as real differences.

Design of the Test

A test of the null hypothesis can be arrived at by the use of a standard experimental design and the analysis of variance (Fisher, 1937). Such experiments consist of counting the parasites removed from fish in a number of independent situations where conditions have been deliberately varied. The experimental data so obtained, however, may be reduced by the analysis of variance only when they meet certain conditions, namely, "that the experimental errors to which the data are subject shall be independently and normally distributed with the same variances" (Cochran, 1938). Data, where the counts are low

numerical values or where they consist of percentages, often occur in the form of non-normal distributions with the means and variances correlated. Under these conditions the errors are not independently and normally distributed. Thus when F or t are to be used to provide a test of the null hypothesis, the data must be transformed in such a way that the errors will be distributed in the required manner.

From an examination of preliminary observations it has been found that where the data consist of counts of parasites or percentages, the errors are not distributed independently with the same variances. In the case where the data consisted of counts of parasites it was found that the square-root transformation (Snedecor, 1940) was applicable and in the case where the data consisted of percentages it was found that the equivalent angle transformation (Snedecor, 1940) was applicable. Thus it was judged that if appropriate transformations of the data were made, then the analysis of variance could be used for testing the null hypothesis in this investigation.

It was decided that certain parts of the null hypothesis, i.e., those involving variations in the number of parasites between different fish, variations between the counts of different workers and variations associated with different time intervals between immersion and counting should be tested by one experiment utilizing the *Latin square* design (Fisher, 1937). The remaining part of the null hypothesis, namely, that involving the assay of cresol solutions of different concentrations was tested by another experiment based upon the randomized block design.

The Latin square provides a means by which the relative significance of three factors in a particular situation may be judged. The experimental procedure following the pattern of the square consisted of counting the *Gyrodactylus* in 5 solutions of cresol in which 5 goldfish were used, one in each solution. The counts were made by 5 workers and the time interval between immersion and counting was divided into 5 periods. It was then possible, after the square-root transformation had been made with the data, to segregate the total variability of counts of parasites into the parts associated with each of the three factors and to test each part of the null hypothesis by means of F or t.

The experimental procedure used to assay the different concentrations of cresol consisted of measuring the proportion of *Gyrodactylus* removed from goldfish at five concentrations. The experiment was designed to obtain four independent estimates of the percentage of organisms removed from the fish at each concentration according to the 10-minute standard mentioned above. Such an experiment meets the specifications for the randomized block design. It was then possible, after the percentages had been transformed to equivalent angles, to segregate by the analysis of variance the proportion of the total variation associated with the concentration of the solution and to test the null hypothesis by means of F or t.

Experimental Operations and Data

For the first experiment a solution of cresol[1] was made up with a concentration of 1:8,000 using distilled water; 50 cubic centimeters of this solution were placed in each of five beakers of 300 cubic centimeter capacity. In each beaker one infested goldfish was immersed for 3 minutes. The parasites in the five solutions were then counted 5 times by 5 different workers in a random order with the one restriction that each worker counted each solution only once. Each of the 5 sets of counts took about 25 minutes to perform. The counts were made by placing a 1 cubic centimeter sample of the solution on a special microscope and counting the parasites therein. The counts, in terms of the number of organisms per cubic centimeter, are shown in Table 1.

Table 1.—Counts of Gyrodactylus made by five workers (Roman numerals) on five goldfish (capital letters), and at five different intervals after immersion (arabic numerals)

[The counts represent the numbers of organisms per cubic centimeter of solution and must be multiplied by 50 to represent the total number of organisms removed from the fish.]

Time interval between immersion and counting	Workers					Time averages	Fish averages
	I	II	III	IV	V		
1	A 20	B 11	C 9	D 0	E 77	23.4	A 11.2
2	B 12	A 15	E 34	C 11	D 2	14.8	B 10.2
3	E 55	D 4	A 8	B 9	C 5	16.2	C 9.2
4	C 7	E 61	D 4	A 9	B 13	18.0	D 2.8
5	D 4	C 14	B 6	E 42	A 4	13.2	E 53.8
Worker averages	19.6	21.0	12.2	17.5	20.5	....	....

Since the data in Table 1 consist of counts of organisms it was necessary, as suggested above, that they be transformed to a new function if they were to be used in the analysis of variance. Accordingly, to each count the number 0.5 was added and the square root of the resulting sum was extracted. Using the transformed values of the

Table 2.—Summary of the analysis of variance using the transformed data from Table 1

Source of variance	Sums of squares	Degrees of freedom	Variances	*F*
Total	100.0761	24	.....	
Fish	87.7631	4	21.9408	35.06***
Workers	3.3853	4	0.8463	1.35
Time	1.4177	4	0.3544	0.56
Error	7.5100	12	0.6258	.....

[1] *Liquor cresolis compositus*—U. S. Dispensatory, 21st edition, p. 628.

Table 3.—Percentage of Gyrodactylus, *with reference to the 10-minute standard, removed from goldfish using five concentrations of cresol, with four replications*

Concentration	Replicates				Averages
	I	II	III	IV	
1:20,000	79.7	71.1	74.5	89.5	78.7
1:10,000	85.0	96.2	92.6	95.3	92.3
1:6,666	98.5	97.3	97.3	97.0	97.5
1:5,000	100.0	100.0	99.0	96.9	99.0
1:4,000	96.6	100.0	96.8	99.0	98.1

counts, an analysis of variance was made. A summary of the analysis is shown in Table 2.

The values in Table 2, Column *F*, show the results of the *F* test. Using Snedecor's table of *F* the following statements may be made: (1) The variation in counts made from the different fish is highly significant. (2) The variation in counts made by different workers is not significant. (3) The variation in counts made at different times is not significant.

For the second experiment 5 different concentrations were selected (1:4,000, 1:5,000, 1:6,666, 1:10,000, and 1:20,000) and in 2 beakers of 300-cubic-centimeter capacity 50 cubic centimeters of solution for each concentration were placed. A goldfish was placed in the first beaker for 5 minutes and was then transferred to the second beaker for 5 minutes. Counts were made from all of the beakers. Thus it was possible to calculate the percentage of organisms for each concentration removed in the first 5 minutes based upon the total for 10 minutes. The percentages are shown in Table 3.

As mentioned above, the data, when they consist of percentages, must be transformed to equivalent angles when used in the analysis of variance. Each percentage value in Table 3, therefore, was converted to its equivalent angle according to Snedecor's table. The analysis of variance was then made on the transformed data and is shown in summary form in Table 4. By comparing the ratios of variances with Snedecor's table of *F* it may be concluded that the variations in the per cents of *Gyrodactylus* removed by the various concentrations were highly significant.

Meaning and Significance

From the first experiment it was learned that the goldfish were extremely variable with respect to the number of parasites that were removed from them. This conclusion can also be seen from the average number of parasites recorded for each fish in Table 2. Thus, if the

Table 4.—Analysis of variance using the transforming data from Table 3

Source of variance	Sums of squares	Degrees of freedom	Variances	*F*
Total	1709.87	19	.....	.....
Concentration	1371.65	4	342.19	15.2**
Error	338.22	15	22.55	.....

method is to be used for estimating the average intensity of infestation in a group of fish, the number of fish used in the sample is an important consideration.

The conclusion that the variations in the counts made by different workers are not significant indicates that the sampling procedure might be repeated quite accurately by different workers. The variations in the counts after different time intervals up until about 2 hours after immersion were not significant and it appears that the organisms do not disintegrate or become attached to the beakers for a reasonable time after immersion.

The concentrations (1:4,000, 1:5,000, and 1:6,666) removed more than 95 per cent of the parasites and were judged to be satisfactory. The concentrations (1:10,000 and 1:20,000) removed less than 95 per cent of the parasites and were judged as not satisfactory. It should be mentioned here that a significant interaction may exist between the concentration and the immersion time. In the present study it was found that the variations in the counts made at different times after immersion were not significant when a cresol concentration of 1:8,000 was used. Since there is the possibility that stronger concentrations will cause the organisms to disintegrate very rapidly a test with the stronger concentrations is needed.

Conclusion

From the experimental results of this study it is concluded that under certain conditions cresol provides a useful method for estimating the number of ectoparasites infesting a population of fish. The method can be used with modern experimental designs to provide a quantitative judgment of the differences in the degree of infestation of groups of fish. It is hoped that the method will be used as a "yardstick" for solving some of the complex questions involved in the treatment of ectoparasites infesting hatchery fish.

Acknowledgments

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GROWTH OF THE ROCK BASS, *AMBLOPLITES RUPESTRIS* (RAFINESQUE), IN FIVE LAKES OF NORTHEASTERN WISCONSIN

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ABSTRACT

The forms of the growth curves of rock bass from four lakes in northeastern Wisconsin with medium-hard to hard water bore a general resemblance to each other, but differed sharply from the curve for rock bass from a lake with extremely soft water. With the exception of a slight increase in growth in the third year of life the annual increments of length of the rock bass of Nebish Lake (4.0 p.p.m. of bound CO_2) tended to decrease consistently beyond the first year. The good first-year growth in length of rock bass of Allequash, Silver, and Trout Lakes (16.8, 15.0, and 18.7 p.p.m., respectively, of bound CO_2) was followed by poor growth in the second, third, and fourth years of life. This poor growth was followed in turn by good growth in the fifth and sixth years. The annual increments of length tended to decline beyond the sixth year of life. The growth of rock bass of Muskellunge Lake (10.0 p.p.m. of bound CO_2) declined sharply in the second year of life. The annual increments of length were fairly constant in the second to seventh years, inclusive, but declined beyond the seventh year. In each lake the males grew more rapidly than the females.

The time of attainment of the legal total length of 7 inches in the different lakes ranged from late in the sixth growing season in Nebish and Trout Lakes to the middle of the eighth growing season in Muskellunge Lake.

Rock bass of corresponding length from Allequash, Silver, and Trout Lakes were so nearly of the same weight that one curve described the length-weight relationship of the three stocks. Muskellunge Lake rock bass were considerably lighter than fish of the same length from these three lakes, and Nebish Lake rock bass were somewhat lighter than those from Muskellunge Lake.

INTRODUCTION

Increasing recognition is being given to the importance of studies of growth rate in connection with fishery management. It has been stated repeatedly that the rate of growth reflects the suitability of a lake or stream for a particular species, and that sound management, especially stocking programs, cannot be developed without a knowledge of the growth rate of fish in different waters. If growth is slow, it is said, food is scarce or the fish are overcrowded and no stocking of that species should be made. On the other hand, fish may be stocked in waters where growth is good.

In actual practice, applications of growth-rate studies to fishery management have not been widespread. For many of our game fishes and panfishes the available information on growth rate is so scanty that we are without proper standards from which to judge whether the growth observed in a particular locality is to be considered

good or poor. The effective use of growth-rate studies as a tool of fishery management will require sufficiently extensive data on the variations of growth rates of important species in different waters to permit the accurate evaluation of the quality of growth in any single locality. These necessary data can be accumulated but slowly and through the combined efforts of numerous investigators.

The present paper is a contribution to the available information on the growth of the rock bass in the lakes of the northeastern highlands of Wisconsin. Although the collections of rock bass from Allequash, Silver, and Trout Lakes were small, it is believed that the general growth curves based on them are reasonably dependable, and that these curves, together with data on the growth of the rock bass of Muskellunge Lake and Nebish Lake, provide a fair idea of the general rate of growth of rock bass and of the variations in growth rate to be expected in the lakes of that region. The data on the growth of the Nebish Lake rock bass have been taken from a paper by Hile (1941).

Limnological data[1] (Table 1) reveal considerable differences among the five lakes. In size they range from Nebish Lake with a surface area of only 38.5 hectares (95 acres) to Trout Lake with an area of 1,583 hectares (3,912 acres). The maximum depths range from 7.5 meters (25 feet) in Allequash Lake to 35.0 meters (115 feet) in Trout Lake. For lakes of this region the waters of Trout, Allequash, Silver, and Muskellunge Lakes may be termed medium hard to hard. Nebish Lake has extremely soft water. The organic matter of the plankton is greater in Allequash Lake than in any one of the other four. This high production of plankton is associated with relatively low transparency (only 1.5 meters).

An earlier study of the growth of rock bass in Trout and Muskellunge Lakes was made by Wright (1929). His data will not be compared with those of the present study since he had no individual sex records and employed a method for the computation of growth histories from scale measurements different from the one used here.

Table 1.—Limnological data concerning five lakes of the northeastern highland district, Wisconsin

[The data on bound CO_2 and organic matter of the plankton refer to average surface conditions.]

Lake	Area (hectares)	Maximum depth (meters)	Average depth (meters)	Secchi disk transparency (meters)	Bound CO_2 (p.p.m.)	Organic matter of plankton (p.p.m.)
Allequash	142	7.5	....	1.5	16.8	1.48
Muskellunge	372.3	21.0	7.0	4.0	10.0	1.16
Nebish	38.5	15.8	5.2	6.0	4.0	0.77
Silver	87.3	19.5	11.3	5.5	15.0	0.85
Trout (North Basin)	533	31.0	12.9	5.0	18.5	0.66
Trout (South Basin)	1,050	35.0	14.2	4.5	18.7	0.92

[1]The data of Table 1 were made available through the courtesy of Dr. Chancey Juday of the Wisconsin Geological and Natural History Survey.

Materials and Methods

The months and years of capture of the rock bass employed for the study of age and growth were: Allequash Lake—August, 1930 (20 fish); Muskellunge Lake—July, August, and September, 1930-1932 (533 fish); Silver Lake—July and August, 1930 and 1931 (154 fish); Trout Lake—July, August, and September, 1930 (77 fish). For data on materials from Nebish Lake see Hile (1941). The collections were taken by gill nets and by hook-and-line fishing. In order to minimize selection, gill nets of four to seven different mesh sizes were included in each set and only small hooks were employed in fishing by hook and line. Even so, the data for certain of the younger age groups were excluded as not representative. Only those age groups for which complete records of sex were available were employed in the study of growth.

Lengths and weights of fish for which records of sex were lacking, and the use of data from certain additional collections taken in 1928, 1931, and 1932 made available a total of 941 specimens for the study of the length-weight relationship of rock bass from Allequash, Silver, and Trout Lakes, and 1,646 specimens for the study of the length-weight relationship of the Muskellunge Lake rock bass.

Scales for the investigation of growth were mounted on glass slides and examined and measured with the aid of a microprojection apparatus. Details as to the method of measuring the scales and calculating the growth from scale measurements were given by Hile (1941). It was assumed that the method of calculating growth, established empirically from a study of the body-scale relationship of rock bass from Muskellunge and Nebish Lakes, was applicable to the data on rock bass from Allequash, Silver, and Trout Lakes.

Growth in Length and Weight

Only general growth curves will be presented since, with the exception of the Muskellunge Lake and Silver Lake collections, the numbers of fish were so small that the data for the individual age groups could not be considered dependable. (Data on the age and year-class composition of samples of rock bass from Muskellunge and Silver Lakes and on annual fluctuations in the growth of certain year classes of rock bass in those lakes were included by Hile (1941) in a study of factors affecting the growth and abundance of rock bass in the lakes of northeastern Wisconsin.) In general, the lengths in Table 2 are grand average calculated lengths, although the successive addition of grand average increments of calculated length was employed to determine the lengths in the later years of life. The use of average increments effects a natural smoothing of the growth curves. The growth curves as determined from a combination of the data for the sexes are presented in Figure 1.[2] The vertical scales of the figure are given

[2]I am indebted greatly to Dr. Frank W. Jobes who prepared the figures for this paper.

Table 2.—Calculated standard lengths at the end of each year of life of rock bass from five lakes of northeastern Wisconsin

[Number of specimens indicated in parentheses]

Lake	Sex	Calculated length in millimeters at end of year of life										
		1	2	3	4	5	6	7	8	9	10	11
Allequash	Male	37	58	75	94	117	139	152	163	....	....	....
		(11)	(11)	(11)	(11)	(11)	(8)	(6)	(2)	....	....	....
	Female	36	52	69	88	110	128	142	150	159	165	....
		(9)	(9)	(9)	(9)	(8)	(6)	(4)	(1)	(1)	(1)	....
	Both	36	55	72	91	114	134	147	156	....	....	....
Muskellunge	Male	33	51	69	88	107	124	142	157	172	180	186
		(220)	(220)	(220)	(208)	(190)	(166)	(138)	(103)	(38)	(9)	(1)
	Female	33	51	68	86	103	119	135	147	160	170	179
		(313)	(313)	(313)	(300)	(272)	(244)	(199)	(162)	(69)	(25)	(3)
	Both	33	51	68	87	105	122	138	152	166	175	182
Nebish	Male	35	62	92	119	139	153	163	171	177	184	191
		(395)	(395)	(395)	(346)	(322)	(269)	(254)	(207)	(79)	(18)	(3)
	Female	34	62	90	113	130	142	150	156	162	168	174
		(586)	(586)	(586)	(519)	(488)	(430)	(396)	(220)	(195)	(72)	(21)
	Both	34	62	91	116	134	147	156	163	169	176	182
Silver	Male	31	48	70	88	118	142	166	179	186	....	....
		(59)	(59)	(59)	(41)	(37)	(8)	(3)	(2)	(2)	....	....
	Female	31	48	68	86	112	133	154	173	181	....	....
		(95)	(69)	(95)	(95)	(69)	(31)	(9)	(4)	(3)	....	....
	Both	31	48	69	87	115	138	160	176	184	....	....
Trout	Male	32	50	70	93	123	153	171	186	195	....	....
		(25)	(25)	(25)	(24)	(23)	(7)	(7)	(4)	(2)	....	....
	Female	32	52	72	93	119	141	154	168	177	183	....
		(52)	(52)	(52)	(50)	(45)	(23)	(19)	(12)	(5)	(1)	....
	Both	32	51	71	93	121	147	162	177	186	....	....

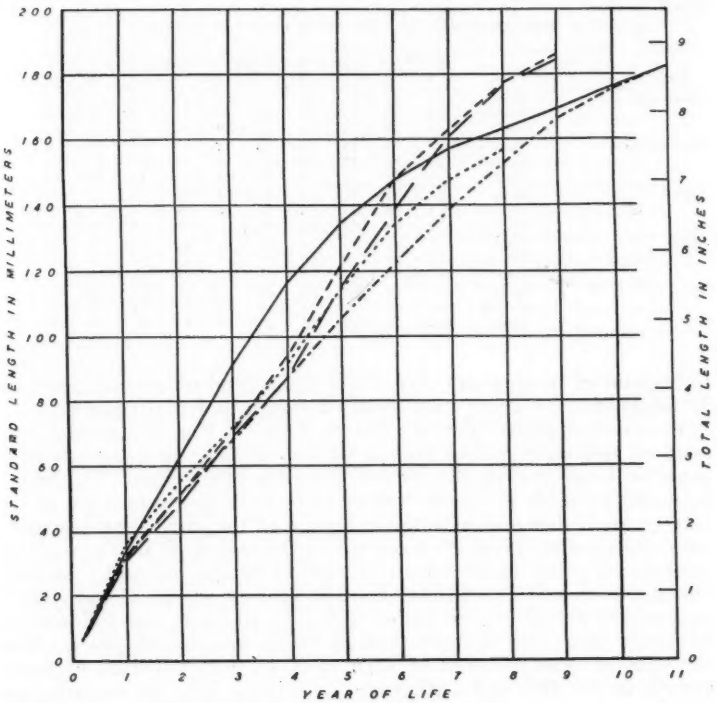

Figure 1.—Calculated growth in length (data for the sexes combined) of rock bass from Allequash Lake (dotted line), Muskellunge Lake (dots and dashes), Nebish Lake (solid line), Silver Lake (long dashes), and Trout Lake (short dashes)

in terms of both standard length in millimeters and total length in inches.

Each stock of rock bass was characterized by sex differences in growth rate, with the males showing the more rapid growth in the later years of life. This condition appears to be characteristic of centrarchids. The age at which a sex difference in length was clearly established varied in the different populations. The earliest years of life, by the end of which the males averaged 5 millimeters or more longer than the females, were: Allequash Lake—second year of life (very few specimens); Muskellunge Lake—sixth year; Nebish Lake—fourth year; Silver Lake—fifth year; Trout Lake—sixth year. The maximum difference between the calculated lengths of males and females in corresponding years of life ranged from 12 millimeters in Muskellunge

Table 3.—Calculated increments of standard length in each year of life of rock bass from five lakes of northeastern Wisconsin

Lake	Sex	Calculated increment of length in millimeters in year of life										
		1	2	3	4	5	6	7	8	9	10	11
Allequash	Male	37	21	17	19	23	22	13	11	....	....	....
	Female	36	16	17	19	22	18	14	8	9	6	....
	Both	36	19	17	19	23	20	13	9	....	....	....
Muskellunge	Male	33	18	18	19	19	17	18	15	15	8	6
	Female	33	18	17	18	17	16	16	12	13	10	9
	Both	33	18	17	19	18	17	16	14	14	9	7
Nebish	Male	35	27	30	27	20	14	10	8	6	7	7
	Female	34	28	28	23	17	12	8	6	6	6	6
	Both	34	28	29	25	18	13	9	7	6	7	6
Silver	Male	31	17	22	18	30	24	24	13	7	....	....
	Female	31	17	20	18	26	21	21	19	8	....	....
	Both	31	17	21	18	28	23	22	16	8	....	....
Trout	Male	32	18	20	23	30	30	18	15	9	....	....
	Female	32	20	20	21	26	22	13	14	9	6	....
	Both	32	19	20	22	28	26	15	15	9	....	....

Lake (end of ninth year) and Silver Lake (end of seventh year) to 18 millimeters in Trout Lake (end of eighth and ninth years).

The general growth curves (Tables 2 and 3, Fig. 1) reveal a pronounced difference in the growth of Nebish Lake rock bass as compared with the growth of rock bass from the other lakes. The length increments (Table 3) of the Nebish Lake rock bass were large in the early years of life and with the exception of the third year decreased consistently with increase of age up to the eighth or ninth year, beyond which point the increments tended to remain constant. In Allequash, Silver, and Trout Lakes the first-year growth of 31 to 37 millimeters (the actual growth varied with lake and sex) was followed by relatively poor growth in the second, third, and fourth years. This slow growth was followed in turn by a secondary period of rapid growth in the fifth and sixth years (continued into the seventh year of life of the Silver Lake fish). The only exception to this trend was provided by the sixth-year increment of Allequash Lake females. Beyond the sixth or seventh year the growth increments of rock bass from these three lakes tended to decrease with increase in age. The growth increments of the Muskellunge Lake rock bass decreased sharply in the second year and thereafter exhibited only unimportant fluctuations (maximum of 2 millimeters in each sex) up to the end of the seventh year of life. The length increments tended to decrease beyond the seventh year. The growth of the Muskellunge Lake rock bass differed from the growth of rock bass in Allequash, Silver, and Trout Lakes chiefly in the absence of the secondary period of rapid growth.

Because of the differences in the style of growth the Nebish Lake rock bass had greater calculated lengths than the rock bass from the other four lakes in the second to sixth years of life inclusive. (The sixth-year length of male rock bass from Trout Lake provides a single exception.) The advantage of the Nebish Lake fish increased from the second to the fourth year, but with the exception of the Muskel-

lunge Lake rock bass in the fifth year, the Nebish Lake fish had the lowest annual increments of length in the fifth to ninth years, inclusive. The Trout Lake rock bass had practically overtaken the Nebish Lake fish by the end of the sixth year and had distinctly the higher calculated lengths beyond the sixth year. Similarly, Silver Lake rock bass were longer than Nebish Lake fish in the seventh and later years of life. The length of the Muskellunge Lake females first surpassed that of the Nebish Lake females in the tenth year; this advantage was increased slightly in the eleventh year. However, the Muskellunge Lake males did not overtake the Nebish Lake males, although they reduced the advantage of the Nebish Lake fish substantially. The data for the Allequash Lake rock bass must be recognized as inadequate. The available information indicates the Nebish Lake rock bass to have been consistently longer than Allequash Lake fish of corresponding age throughout the later years of life.

From the standpoint of conservation the course of growth during the early years of life may not be of particularly great significance. It is more important to know the age at which legal length is attained and the relationship of age to size among fish above legal length. In the inland lakes of Wisconsin the size limit for rock bass is 7 inches, total length (146 millimeters, standard length). This length was attained by the rock bass from Nebish Lake and Trout Lake toward the end of the sixth growing season, by the Silver Lake rock bass in the first half of the seventh growing season, by the Allequash Lake rock bass toward the close of the seventh growing season, and by the Muskellunge Lake rock bass near the middle of the eighth growing season. Actually, the males of each lake required somewhat less time and females somewhat more time than indicated in the preceding sentence to reach legal size. The data of Table 2 suggest that males attain legal length about a year sooner than females (less than a year in some lakes; more than a year in others).

If attention is confined to fish above legal length, the Nebish Lake rock bass, in spite of its rapid growth in early years, must be classified as a stock with poorer growth than was found in Silver Lake and Trout Lake.

The calculated weights of Table 4 (see also Table 5 and Fig. 2), which correspond to the calculated lengths of Table 2, were computed by means of the length-weight equations given in the next section of this paper. The fact that the Nebish Lake rock bass weighed less than fish of corresponding length from the other four lakes places the growth of the Nebish Lake rock bass in a less favorable light when growth is expressed in terms of weight rather than length. Similarly the slow growth of the Muskellunge Lake rock bass is accentuated by the fact that fish from that lake had lower average weights than fish of the same length from Allequash, Silver, and Trout Lakes. The calculated weights of the Nebish Lake rock bass were greater than those of rock bass from the other four lakes in the second to fifth years,

Table 4.—Calculated weights (corresponding to the calculated lengths of Table 2) at the end of each year of life of rock bass from five lakes of northeastern Wisconsin

Lake	Sex	Calculated weight in grams at end of year of life										
		1	2	3	4	5	6	7	8	9	10	11
Allequash	Male	2	7	14	29	56	95	125	154	....	....	....
	Female	2	5	11	23	46	74	101	120	143	160	....
	Both	2	6	12	26	51	84	113	137	....	....	....
Muskellunge	Male	1	4	10	21	38	59	88	119	157	179	198
	Female	1	4	10	20	34	52	76	98	126	151	176
	Both	1	4	10	20	36	56	82	108	141	165	187
Nebish	Male	1	7	23	49	79	105	127	146	162	182	204
	Female	1	7	21	42	64	84	99	111	124	139	154
	Both	1	7	22	46	72	95	113	128	143	160	179
Silver	Male	1	4	12	23	57	101	163	205	231	....	....
	Female	1	4	11	22	49	83	130	185	212	....	....
	Both	1	4	11	22	53	92	146	195	222	....	....
Trout	Male	1	4	12	28	65	127	178	231	267	....	....
	Female	1	5	13	28	59	99	130	169	198	220	....
	Both	1	4	12	28	62	113	154	200	232	....	....

inclusive, with the single exception of the Allequash males at the end of the second year. At the end of the sixth year the Nebish Lake fish weighed less than rock bass from Trout Lake and were only slightly heavier than Silver Lake fish. At the end of the seventh year of life Trout Lake and Silver Lake rock bass of both sexes and the Allequash Lake females weighed more than the Nebish Lake fish, and in the eighth and later years Nebish Lake rock bass were consistently lighter than fish of corresponding age from the former three lakes. Attention is called particularly to the large increments of weight of the Silver Lake and Trout Lake rock bass in the sixth to eighth years of life. The unweighted means for the sexes show that at the end of the ninth year Nebish Lake fish weighed only a little more than 5 ounces, as compared with a weight of about 8 ounces for rock bass from Silver and Trout Lakes. With increase in age the Muskellunge Lake males reduced substantially the advantage of the Nebish Lake males but remained the lighter in all the later years of life. The females from Muskellunge

Table 5.—Calculated increments of weight in each year of life of rock bass from five lakes of northeastern Wisconsin

Lake	Sex	Calculated increment of weight in grams in year of life										
		1	2	3	4	5	6	7	8	9	10	11
Allequash	Male	2	5	7	15	27	39	30	29	....	....	....
	Female	2	3	6	12	23	28	27	19	23	17	....
	Both	2	4	6	14	25	33	29	24	....	....	....
Muskellunge	Male	1	3	6	11	17	21	29	31	38	22	19
	Female	1	3	6	10	14	18	24	22	28	25	25
	Both	1	3	6	10	16	20	26	26	33	24	22
Nebish	Male	1	6	16	26	30	26	22	19	16	20	22
	Female	1	6	14	21	22	20	15	12	13	15	15
	Both	1	6	15	24	26	23	18	15	15	17	19
Silver	Male	1	3	8	11	34	44	62	42	26	....	....
	Female	1	3	7	11	27	34	47	55	27	....	....
	Both	1	3	7	11	31	39	54	49	27	....	....
Trout	Male	1	3	8	16	37	62	51	53	36	....	....
	Female	1	4	8	15	31	40	31	39	29	22	....
	Both	1	3	8	16	34	51	41	46	32	....	....

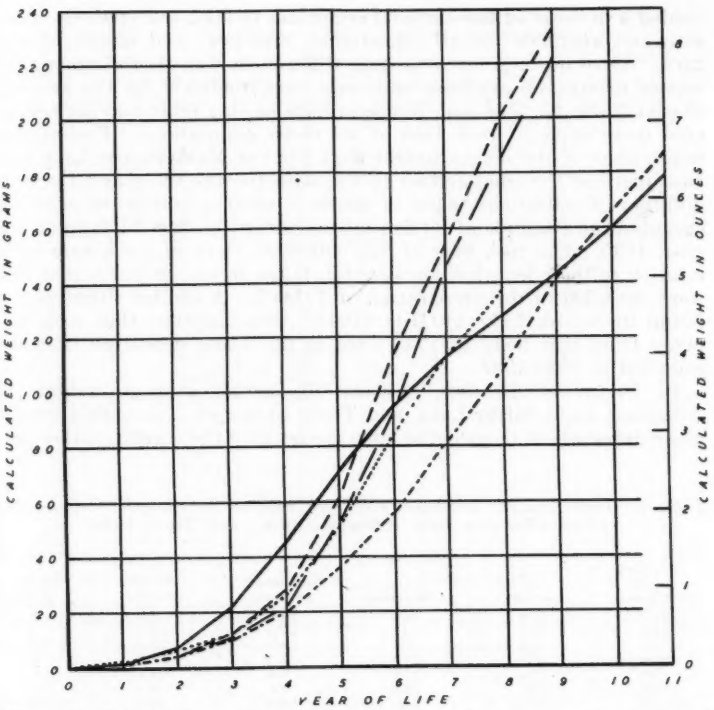

Figure 2.—Calculated growth in weight (data for the sexes combined) of rock bass from Allequash Lake (dotted line), Muskellunge Lake (dots and dashes), Nebish Lake (solid line), Silver Lake (long dashes), and Trout Lake (short dashes)

Lake, however, weighed more than females from Nebish Lake in the ninth, tenth, and eleventh years of life.

For the present, the problem of the factors contributing to the observed differences in the growth of the rock bass in the various lakes must remain unanswered. Possibly some significance may be attached to the fact that the general growth curves of the rock bass from lakes with medium-hard to hard water (especially Allequash, Silver, and Trout Lakes) were in general similar, but differed sharply from the growth curve of the rock bass from the soft water of Nebish Lake.

Length-Weight Relationship

The preliminary tabulations of the data on the length-weight relationship of the rock bass from Allequash, Silver, and Trout Lakes in-

cluded a division of the material according to lake, sex (records of sex were not available for all collections), and year and month of capture. Since no large or consistent differences were found among the several groups, all available materials were combined for the preparation of Table 6. The length-weight data of this table may be considered descriptive of rock bass of all three populations. Preliminary tabulations of the length-weight data for the Muskellunge Lake rock bass justified the combination of the data for the sexes and the combination of collections taken in different months and years, with the exception of a sample of 89 fish taken during the first 17 days of August, 1935. The rock bass of this collection were so much heavier in relation to their length than were fish taken in earlier years that they were excluded in the preparation of Table 7. A similar situation was found in Nebish Lake by Hile (1941), who observed that rock bass taken from that body in 1935 were in far better condition than fish collected in 1930-1932.

In Figure 3 the dots indicate the actual average weights of Allequash Lake, Silver Lake, and Trout Lake rock bass within 5-millimeter intervals of length; the open circles give the corresponding data

Table 6.—Length-weight relationship of rock bass as determined from the combined collections from Allequash, Silver, and Trout Lakes

Standard length (millimeters)	Weight (grams)		Total length (inches)	Weight (ounces)	Number of fish
	Actual	Calculated			
217	374	370	10.4	13.2	1
212	415	344	10.1	14.6	1
207	334	320	9.9	11.8	1
202	288	297	9.6	10.2	5
197	274	275	9.4	9.7	7
192	247	254	9.2	8.7	13
187	226	235	8.9	8.0	10
182	220	216	8.7	7.8	10
177	202	198	8.4	7.1	11
172	184	182	8.2	6.5	20
167	171	166	8.0	6.0	17
162	154	151	7.7	5.4	26
157	147	137	7.5	5.2	19
152	122	125	7.3	4.3	20
147	115	112	7.0	4.1	30
142	101	101	6.8	3.6	34
137	88	91	6.6	3.1	41
132	81	81	6.3	2.9	61
127	71	72	6.1	2.5	68
122	65	64	5.8	2.3	51
117	56	56	5.6	2.0	53
112	49	49	5.4	1.7	73
107	43	43	5.1	1.5	53
102	35	37	4.9	1.2	39
97	31	32	4.7	1.1	27
92	28	27	4.4	1.0	27
87	22	23	4.2	0.8	18
82	18	19	3.9	0.6	37
77	16	16	3.7	[1]0.5	35
72	12	13	3.5	0.4	20
67	11	10	3.2	0.4	9
62	8	8	3.0	0.3	4

[1]Actual value is 0.56.

Table 7.—Length-weight relationship of the Muskellunge Lake rock bass as determined from the combined collections of 1928 and 1930-1932

Standard length (millimeters)	Weight (grams)		Total length (inches)	Weight (ounces)	Number of fish
	Actual	Calculated			
207	267	272	9.9	9.4	3
202	259	253	9.6	9.1	8
197	239	235	9.4	8.4	8
192	224	218	9.2	7.9	13
187	205	201	8.9	7.2	22
182	191	185	8.7	6.7	34
177	172	171	8.4	6.1	48
172	159	157	8.2	5.6	48
167	145	143	8.0	5.1	37
162	129	131	7.7	4.6	54
157	117	119	7.5	4.1	77
152	107	108	7.3	3.8	78
147	97	98	7.0	3.4	78
142	87	88	6.8	3.1	82
137	80	79	6.6	2.8	68
132	72	71	6.3	2.5	59
127	62	63	6.1	2.2	40
122	54	56	5.8	1.9	58
117	49	50	5.6	1.7	51
112	43	43	5.4	1.5	43
107	36	38	5.1	1.3	52
102	32	33	4.9	1.1	91
97	28	28	4.7	1.0	92
92	23	24	4.4	0.8	89
87	20	20	4.2	0.7	148
82	17	17	3.9	0.6	124
77	15	14	3.7	0.5	64
72	11	12	3.5	0.4	55
67	11	9	3.2	0.4	19
62	6	7	3.0	0.2	2
57	..	6	2.7	....	..
52	4	4	2.5	0.1	1

for the Muskellunge Lake rock bass. The curves that follow through the two sets of points are solutions of the parabolas:

$$W = 2.667 \times 10^{-5} L^{3.057},$$

and $$W = 3.307 \times 10^{-5} L^{2.986},$$

where W = weight in grams,

and L = standard length in millimeters.

The first of the above equations applies to the rock bass from Allequash, Silver, and Trout Lakes and the second to the Muskellunge Lake rock bass.

For comparison a curve showing the length-weight relationship of Nebish Lake rock bass taken in late July and early August of 1930-1932 has been included in Figure 3. This curve is a graph of the equation:

$$W = 2.884 \times 10^{-5} L^{3.003}$$

Complete tabular data on the length-weight relationship of the Nebish Lake rock bass may be found in a publication by Hile (1941).

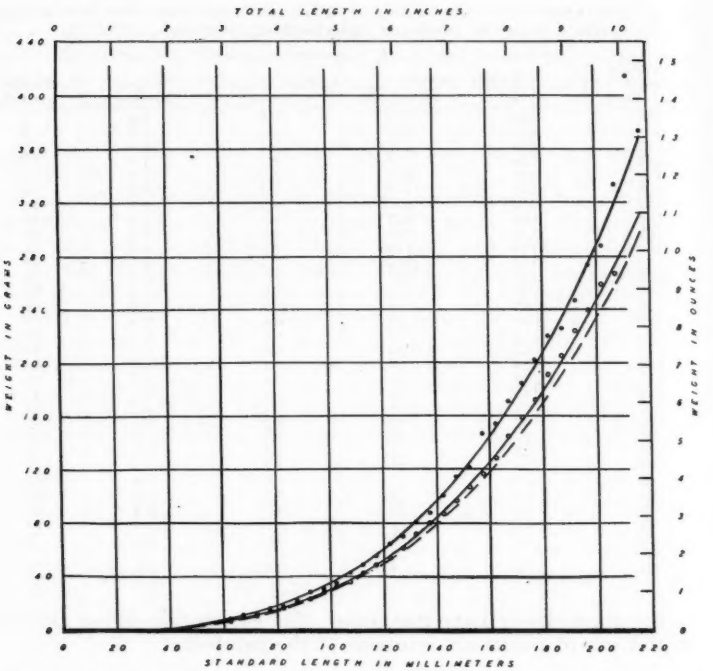

Figure 3.—Length-weight relationship of rock bass from Allequash, Silver, and Trout Lakes (dots) and Muskellunge Lake (open circles). The smooth curves passing through the two sets of points are graphs of the length-weight equation. The broken curve shows the length-weight relationship of the Nebish Lake rock bass (empirical data not plotted).

The relatively low weights of the Nebish Lake fish provide a ready explanation for the fact that the growth of the Nebish Lake rock bass appears less favorably in comparison with rock bass of the other lakes when growth is expressed in terms of weight instead of length. At the legal length of 7 inches the Nebish Lake rock bass weighed only 3.2 ounces as compared with 3.4 ounces for the Muskellunge Lake rock bass and 3.9 ounces for fish from Allequash, Silver, and Trout Lakes. At the length of 9 inches the weights of rock bass from the various lakes were: Nebish Lake, 7.0 ounces; Muskellunge Lake, 7.3 ounces; Allequash, Silver, and Trout Lakes, 8.6 ounces.

In the length-weight relationship as well as in the general form of the growth curves the rock bass from the lakes with medium-hard to

hard water differed from the Nebish Lake rock bass. The agreement of the data for the fish from Allequash, Silver, and Trout Lakes was so close that a combination of all available collections from these three lakes was feasible. It is of some interest that the arrangement of the various populations with respect to relative heaviness follows the arrangement of the lakes as to the hardness of their waters. The heaviest rock bass were taken from Allequash, Silver, and Trout Lakes (16.8, 15.0, and 18.7 p.p.m., respectively, of bound CO_2), and the lightest fish came from Nebish Lake (4.0 p.p.m. of bound CO_2). Muskellunge Lake, with medium-hard water (10.0 p.p.m. of bound CO_2), contained rock bass that were intermediate in relative heaviness.

A summary of this paper may be found in the abstract.

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CONTROL OF FISHING INTENSITY IN MARYLAND

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ABSTRACT

The production of the shad fishery of the Chesapeake Bay has fallen in recent years to approximately one-seventh of its former level. Artificial propagation has not stemmed depletion. Hydrographic, pollution, biological, and statistical studies have eliminated the various causes held by the fishermen to be responsible for this decline except for a single item—overfishing, with the consequent excessive drain on the broad reserve. Researches of the Fish and Wildlife Service of the U. S. Department of the Interior and of the Chesapeake Biological Laboratory indicate that not more than 60 per cent of the spawners should be taken by the fishery (regardless of year class) if an ample brood stock is to be maintained. However, a further reduction of fishing intensity may be necessary in the Chesapeake Bay to rehabilitate the present brood reserve. Actually the annual catch of shad is far in excess of the 60-per-cent level. Tagging records and scale studies show the catch to be approximately 90 per cent of the entire population. In an attempt to reduce the fishing intensity legislation recently was enacted in Maryland.

The new legislation gives to the Department of Tidewater Fisheries the power to refuse all applications for licenses from those persons who did not hold permits to fish during 1940 and 1941. Furthermore, the operators are required to make available to the fishery investigators periodic, accurate reports on season, locality, type of gear, and amount (weight) of the catches. These data are of extreme importance in the determination of the brood reserve and consequent control of the extent of capture.

Biologists are now engaged in the formulation of plans for the systematic collection of biological data (length and weight frequencies and age determinations) with which to supplement data obtained from fishermen. It is expected that the analysis of the data accruing from all sources will provide a body of information from which it will be possible to determine the relative effects of the different types of gears on the fisheries and, in turn, to determine the extent to which the use of these gears should be restricted in order to keep within the biological needs for brood stock. Plans for the ultimate reduction in fishing effort calls first for the stabilization of the effort at the present level. It is expected that little sacrifice will be required of the present operators, who will, in fact, be the first to profit from a restoration of the stock. No new licenses will be issued until the supply of shad justifies such action.

The yield of shad, *Alosa sapidissima*, one of the most important food fishes of the Chesapeake Bay, has decreased, since the turn of the century, from 15,000,000 pounds to less than one-seventh of the former production. This decrease in the yield of shad represents a loss of more than $1,000,000 yearly to the Chesapeake area with all of the attending social and economic effects in the various tidewater sections. Moreover, the decline in abundance contributed to a greater fishing intensity and higher cost per unit of capture since greater effort and

investment have been necessary to provide catches of a size sufficient to afford a livelihood to the fishermen. Although this situation is not new as a problem of fishery management, the particularly critical conditions in the Bay and in other localities in which the abundance of shad has declined, challenged the attention of fishermen, conservation administrators, and biologists alike. The combined efforts of these interested groups have resulted in the formulation of plans of action, and more recently in the enactment of legislation in Maryland which promises to relieve the situation.

A call from the Department of Tidewater Fisheries brought the net fishermen of Maryland together early in 1940 for a preliminary conference on the shad problem. Thereafter developments were in the hands of the fishermen, and public meetings to consider the problem were held by them in all of the fishing centers of the State. It was commonly believed by the fishermen that some or all of the following factors were responsible for the decline in the shad fishery: Pollution; increased activity by fishermen from other States; destruction of breeding grounds; insufficient artificial propagation; headwater dams; motor boats; trawling in the ocean near the Capes; increase in enemies of the shad; and overfishing. At the various meetings the results of hydrographic, pollution, biological, and statistical studies were outlined to them by the scientists present to disprove the suggested causes of depletion except for a single item, overfishing.

Early in their deliberations the commercial men accepted the principle that an aquatic habit can produce only a certain yield of fish and that to maintain this production a certain minimum level of brood stock must be assured. Likewise, they accepted the conclusions based on scale and tagging studies which indicate that virgin fish make up 90 per cent of the catch of shad in a single year, thus leaving a reserve of about 10 per cent for propagation from natural sources, a number equivalent to one-fourth of the minimum deemed essential. With this general situation clear to the fishermen the problem before them became definite, although many difficult economic and administrative questions were involved in its solution. The problem now could be stated, "Can we manage the fishery so that the operators may live on a plane at least comparable to that afforded by their recent income levels, low as they were, and at the same time build up the shad populations to a point that will vastly improve their economic status?" The solution of the problem called for less fishing but not through sudden and disturbing limitations on gears and seasons. It required the fishermen to allow more shad to escape the nets and complete their spawning activities. At the same time the fishermen were impressed with the fact that spawning shad are not lost but are subject to capture, as larger fish, upon their return to the breeding grounds in later years. In short, the suggested remedy called for the catching of fish at a slower rate in order to increase the poundage taken and at the same time bring about an increase in the brood reserve.

It was obvious to the fishermen that they, as a group, cannot expect a continuing worthwhile level of production if an ample brood stock is not left in the water each year. They objected seriously to the usual wel-intended conservation practices of limiting gears and shortening seasons since they were certain that new fishermen would take out licenses as soon as an increase in the supply of shad was realized as a result of these limitations. These new fishermen would benefit from the sacrifices made by those regularly employed. Furthermore, the increased fishing intensity would bring about a new decline in the fishery. It was further brought out that every fisherman had to use sufficient gear to catch enough shad to make a living and that no single fisherman could afford to decrease his fishing effort in any manner if he expected to remain in the business. The fishermen agreed, however, that their gears should be limited by law to their present levels as a step in the direction of controlling fishing intensity. In addition, they became convinced of the value of length-weight data and general catch records and promoted legislation to assure this information to the biologists.

The plan to limit gears to their present levels constituted a very worthwhile and constructive step on the part of the practical men. There remained, nevertheless, the problem of reducing the amount of gear now in operation. The fishermen recognized that every year some men quit fishing for one reason or another. Some of them die, some turn to other occupations, and still others are forced to suspend operations by reason of financial difficulties. It was recommended, therefore, that persons not licensed to operate in 1940 or 1941 be considered as new to the fishery and that no new licenses be issued, until sufficient reduction in gear has taken place to assure the necessary brood reserves. The commercial men and their advisors recognized from the first that this method would take time to remedy the present situation but they deemed it a thoroughly fair and democratic procedure.[1]

Following the development and formulation of a policy for the rehabilitation of the shad, the next step on the part of the fishermen, who early had organized themselves the state-wide group, the Commercial Fishery Advisory Committee of Maryland, was that of having their recommendations enacted into legislation. When the thought of limiting fishing gears through the refusal of licenses was first considered, there was much skepticism as to the possibility of obtaining legal sanction. It developed, however, that as a result of the Advisory Committee's sectional meetings there was a general desire on the part of the fishermen (as expressed in later state-wide meetings) that gears be limited. This fact weighed heavily with the representatives of the tidewater area in the legislature. The measure was passed by the legislature without a dissenting vote either in committee or on the

[1]It is comparable to the Taylor Grazing Act administered by the U. S. Department of Agriculture and many other municipal regulations that restrain the efforts of individuals for the good of themselves as well as for the public welfare.

floor. The Department of Tidewater Fisheries was given jurisdiction in the issuance of licenses and thus obtained the power to refuse permits for new or replacement gears to those persons who were not engaged in fishing operations in either 1940 or 1941. There was also written into the law a requirement that the operators make available to the State fishery investigators periodic, accurate reports on seasons, localities, types of gear, market values, and amounts (weight) of the catches. These data are extremely valuable for the sound control of the fishing rate.

Biologists are now engaged in the setting up of a comprehensive procedure for gathering catch records of every commercially important species captured in State waters in order to obtain a direct check on the effect of the fisheries on populations in Chesapeake Bay. However, catch records, the information submitted by the fishermen, do not in themselves contain enough information to constitute a complete investigation of fish populations, nor do they constitute an adequate basis for determining the effects of the fisheries on these populations. A knowledge of the number of fish in each year class as a basis for calculating the rapidity at which the species is being caught, is essential. Due to the difficulty in determining the age of certain species of fish, the slightly less efficient but biologically sound correlation of fish length with the number of fish in each size group must be employed for some varieties.

The determination of the ages or lengths of all the fish caught is not practical, but data from a series of properly selected samples offer a basis for an accurate estimate of an entire population. To facilitate such population sampling it is proposed to set up within the Bay definite areas according number of nets, types of gear, or some other criterion derived from the fisheries. The establishment of these areas, in which the populations will be subjected to the same type of fishing, will simplify collecting and reduce the labor involved since a sample from any part of such an area will be representative of the entire population of that area. Information will be collected by routine sampling from day to day, week to week, or other selected periods found to be biologically sound. Many preliminary or trial samples will be made to establish the boundaries of these homogeneous areas and the time periods within which the size and age composition of the populations within each one remains constant. Maryland is fortunate in having field employees with experience in collecting shad scales and length measurements and it is from these collectors that representative scale samples and length measurements of the entire commercial catch are expected to be made.

Data from tagging, from catch records, and from length and age determinations will make it possible to determine the effect of a fishery on the entire fish population and, in turn, to suggest a basis for the regulation of the intensity of capture. Proper regulation inevitably would lead to the establishment of a fishery on an economically sound

basis whereby fishermen could realize a maximum amount of fish from a minimum amount of labor and investment, while fish dealers and the consuming public would be assured a continuous supply of fish.

With the stability of an industry so sensitive to marked changes in supply and demand, as is the shad fishery, the assured income of those engaged in that industry is increased. Any increase in the stabilization of the shad fishery will be reflected in other local finfish operations, since the gears are not selective as to species. Thus it is expected that the new regulations will not only be instrumental in the restoration of Maryland's supply of fishes but also will help bring the fishing communities to their former activity and prosperity.

OBSERVATIONS ON THE LIFE HISTORY OF THE NORTHERN PIKE, *ESOX LUCIUS* L., IN HOUGHTON LAKE, MICHIGAN[1]

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ABSTRACT

Male northern pike made up 65 per cent of the 378 adults taken in the upstream weir of the ditches tributary to the north bay of Houghton Lake in April, 1939. An estimated additional 50 fish moved upstream before the weir was installed. The males averaged 21.2 inches, total length, while the females averaged 23.5 inches. In 1940, 58 per cent of the 118 adults were males. Twenty-eight additional spawners (13 males and 15 females) captured outside the experimental area were later added to the 118 fish. The males of the 1940 run averaged 19.8 inches in total length as compared with 23.2 inches for the females. Most of the spawners appeared in the weir between 6:00 p.m. and 9:00 a.m. The average number of days that the adult northern pike spent in the ditches in 1939 was 18.25 (range of 6 to 50 days). In 1940 the average number of days spent in the ditches was 23.9 days (range of 4 to 90 days).

The numbers of young northern pike (aside from an insignificant few that were preserved) that entered the downstream weir from the spawning grounds to Houghton Lake were: 1939—7,239; 1940—1,495. These young were the offspring of 125 potential female spawners in 1939, and of 65 in 1940. The average length of the young increased at a rate of at least 1.8 millimeters per day during the 82 days after the first hatch was observed in 1939, and at least 1.3 millimeters per day during the first 85 days after the first hatch was observed in 1940.

INTRODUCTION

The lack of a satisfactory explanation for the abrupt increases or decreases in the abundance of the northern pike, *Esox lucius* Linnaeus, in some Michigan lakes has brought out strongly the need for more detailed information on the life history and growth rate of this species. The nature and extent of the fluctuations in the catch of northern pike at Houghton Lake, Roscommon County, Michigan, have been determined from creel-census records obtained by conservation officers since 1928. These records show that the quality of fishing for northern pike declined steadily from 1928 to 1931 and was improved during the years 1932 to 1934, with a peak in 1933. By 1935 the abundance of northern pike had again dropped to a low level. When fishing was poor for northern pike, the abundance of pan fish increased. Although Houghton Lake has always had a reputation as one of the best northern pike lakes in Michigan, the decline in abundance of the species in recent years has resulted in numerous complaints by fishermen and resort owners. Previous surveys and examinations revealed that

[1]Contribution from the Michigan Institute for Fisheries Research.

Houghton Lake offered excellent possibilities for studies on the life history of the northern pike. Consequently, the present investigation was started at Houghton Lake in the early spring of 1939 and was continued through that summer and the spring and summer of 1940.

Observations were made on the spawning migration, spawning habits, return of adults and the movement of young to the lake, feeding habits and growth of young and adults, and the migration (other than the spawning migration) of the northern pike. Only the data obtained on the spawning run and return migration of adults and on the production and growth of young northern pike are presented in this paper.

Marsh land adjacent to the shores of Houghton Lake is being reclaimed gradually. Although this practice has increased the number and price of lake lots, it has also decreased the extent of northern pike spawning grounds. This decrease of available spawning territory, together with low water and other unfavorable spawning conditions, is probably responsible, in part at least, for the decrease in the northern pike population. The present study was undertaken, therefore, on the marshes to determine the spawning requirements of the pike, and the extent and character of the spawning grounds still available.

Houghton Lake, one of the most important resort lakes in Michigan, is located in the upper half of the Lower Peninsula. The area of the lake is 20,044 acres, and the maximum depth is 20 feet. Its fame as a popular tourist lake is illustrated by the fact that approximately 100 resorts (hotels, boat liveries, and tourist camps), and at least a thousand private cottages and summer homes are to be found along its shores.

Description of the Spawning Area

Seven streams and many drainage ditches flow into Houghton Lake. Each stream or ditch, and the outlet (Muskegon River) as well, supports a northern pike run almost every year. Fairly extensive low swamp land bordering on the lake shore also may be used for spawning, especially during periods of high lake level. The present investigation was confined mainly to the drainage ditches that flow into the north bay of Houghton Lake at Peterson's Resort (Fig. 1). These dredged ditches provide drainage for the marshes bordering the roads that lead north, south, and west from Peterson's. Of the seven ditches shown on the diagram, only the first four were under observation. The culvert that connects Ditches I and V was plugged to prevent the movement of northern pike from the Muskegon River into the area under observation. The four ditches have a total length of 2¼ miles, a maximum depth of 3 feet, and a width varying from 6 to 15 feet. The bottom is composed of sand and decaying vegetation. The color of the water varies from light to dark brown. Marsh grass (*Calamagrostis canadensis*), which is the dominant plant in the ditches, also grows with willows along the ditch banks. At periods of high water,

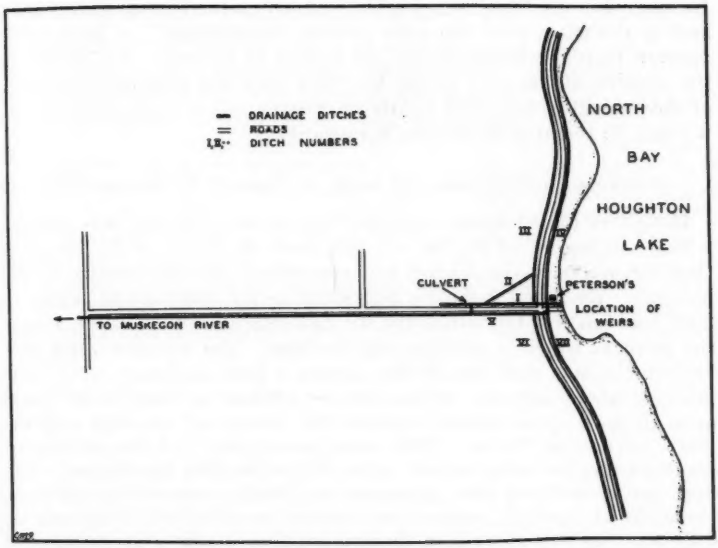

Figure 1.—Diagram of Peterson's drainage ditch system (diagrammatic)

many marsh areas of varying sizes that border on the ditches are flooded. These areas often are used by spawning northern pike, although most of the spawning takes place in the ditches themselves. Most of the ditches become completely dry in late summer.

Description of Fish Weirs

Weirs used to capture young and adult northern pike were installed in Ditch I, approximately 75 feet from the lake (Fig. 1). The maximum depth at this location was 15 inches and the width was 7 feet. The upstream and downstream weirs used to take the adult fish each consisted of three wings. The wings were constructed of plaster lath, 4 feet long, and 5-foot lengths of 1- by 2-inch slats driven into the bottom, 1 inch apart. A barrier of similar contruction placed perpendicular to the ditch banks 15 feet from the apex of the **V** formed by the two wings completed the "pot" in which the fish were impounded. The apex of the **V** headed into the current to catch fish going upstream; the form of the weir was reversed when the fish began to move downstream.

All northern pike fingerlings that migrated from the ditches to Houghton Lake were captured in a **V**-shaped weir whose wings were made by placing window screen (12 meshes to the inch) over wooden

frames. These screens were buried securely in the bottom of the ditch and in the bank, with the apex pointed downstream. A home-made minnow trap of window screen (12 meshes to the inch) was placed in the opening at the apex of the V. This trap was soldered to a piece of sheet metal which fitted tightly in grooves, one in each wing, so that it could be removed by sliding it upwards.

Condition of Ditches and Lake at Time of Spawning Run

Houghton Lake had an extremely high water level and was covered with 18 inches of ice during the last week of March, 1939. At that time the water in the ditches was completely frozen (usually to the bottom). By April 2 the ice and snow in the ditches had begun to melt, and on this date all of the ice had disappeared in Ditch I near the point at which it empties into the lake. The warmer water that entered the lake from the ditches opened a hole in the ice of the lake near the shore and also melted the ice offshore so that in the shoal area an open space existed between the bottom of the lake and the under surface of the ice. This open space permitted the passage of northern pike from the deeper water of the lake into the ditches. The first run of northern pike (estimated at 50 fish) entered the ditch on the night of April 2, before a weir could be installed. Considerable difficulty was experienced in the construction of the weir, because of the frozen banks and ditch bottom. However, it was completed on April 3. The upstream run of northern pike continued until April 25. The ditches were either completely or partially frozen over until April 15. The ice did not disappear completely from Houghton Lake until April 23.

In 1940 Houghton Lake was extremely low, although at the time of the earliest observation on March 16, the water level of the marshes and ditches was higher than in 1939, due to the ice in the culverts and ditches. The water over the broad shoal that extends out in Houghton Lake from the mouth of the ditch was frozen to the bottom. By April 5, approximately 100 feet of the ditch nearest the lake was open, and there was a good flow of water into the lake. The weir was installed on this date. On April 9, a hole about 70 feet in diameter had been opened in the ice of the lake at the mouth of the ditch, and the first northern pike entered the weir on that day. The spawning run continued until April 23. The ditches were almost completely covered with ice until April 15 in the 1940 season. The size of the open spot in the ice cover of the lake at the mouth of the ditch increased almost every day. Occasionally, however, a thin film of ice formed over this opening at night, but this ice did not interfere with the passage of fish and usually broke up during the following day. The general break-up of the ice in Houghton Lake began on April 21 but the ice did not melt completely until April 24.

Observations on the Spawning Runs of 1939 and 1940

Measurements and determinations of sex were made for all northern pike captured on their upstream migration in 1939. At the same time each fish of the 1939 run was marked by fin-clipping. This marking involved a different combination of fins each day (20 different combinations were used; consequently the fish that were taken on the last four days were all given the same mark). As was mentioned in the preceding section, the northern pike that ran upstream on the first night in 1939 (April 2) were not recorded. Jaw tags were affixed to the adults at the time of the downstream migration in 1939 and to the upstream migrants in 1940.

Time and length of the spawning run.—The spawning run of northern pike covered a period of 24 days in 1939 (April 2-April 25). Spawners ran up the ditches over a period of 15 days in 1940 (April 9-April 23). McNamara (1937) made observations on the northern pike run at Chemung Lake, Livingston County, Michigan, over a period of four years, but he did not make specific statements to the dates of the run in any one year. He stated merely that the time of the migration was from late February till the middle of April.

Total number of spawners.—A total of 428 northern pike (including the 50 fish estimated to have run upstream before the weir was installed) entered the ditches in 1939. Of this number, however, 23 females were preserved as specimens; consequently only 405 fish actually proceeded to the spawning grounds. The number of spawners in 1940 was 118.[2] Possible explanations for the smaller run in 1940 are: Northern pike may have been prevented from moving between the lake bottom and the surface ice because of the low lake level in 1940; the lake may have contained fewer adult northern pike in 1940; or the northern pike may have spawned elsewhere. Some evidence for this latter explanation was found in the fact that the run of northern pike at the weir on the Muskegon River was larger in 1940 than in 1939.

Daily number of migrants.—The total daily run of northern pike in 1939 and 1940 is presented in Table 1. In 1939, the largest number of spawners taken in any one day was 53 on April 4. The number of migrants exceeded 25 on only 7 days. The majority of the 1940 spawners entered the weir during the 4-day period, April 14 to 17, with just occasional stragglers entering before and after these dates. No correlation could be found between the temperature of the water in the ditches and the number of fish that ascended.

Hourly variation in the number of migrants.—The number of adult northern pike that entered Peterson's ditches during different periods of the day and the average number per hour within each of these pe-

[2]These 118 fish taken in 1940 did not, however, make up all the northern pike that spawned in Ditches I-IV, since 28 additional fish trapped in a weir in Ditch V were transported to Ditches I-IV. The northern pike captured in Ditch V had ascended from the Muskegon River.

Table 1.—The daily run of northern pike spawners in Peterson's Ditch, April 1939 and 1940

Day of month	Number of males	Number of females	Total number
1939			
2	....	....	[1]50
3	11	4	15
4	32	21	53
5	2	2	4
6	10	16	26
7	6	1	7
8	4	4	8
9	3	3	6
10	1	8	9
11	3	8	11
12	2	3	5
13	12	4	16
14	6	6	12
15	6	3	9
16	22	9	31
17	6	3	9
18	7	9	16
19	11	0	11
20	20	7	27
21	17	12	29
22	20	6	26
23	22	2	24
24	11	0	11
25	13	0	13
Total	247	131	[2]428
1940			
9	3	....	3
10	6	1	7
11	2	....	2
12	1	1	2
13	2	1	3
14	8	5	13
15	12	12	24
16	13	11	24
17	9	6	15
18	1	3	4
19	....	4	4
20	1	3	4
21	1	1	2
22	7	2	9
23	2	....	2
Total	68	50	118

[1]Estimated to have entered ditch on first night of the run.

[2]Includes the 50 fish that ran upstream on first night and also the 23 females retained as specimens.

riods are shown in Table 2 for 1939 and 1940 and for the 2 years combined. The largest number of fish entered the weir in the 3-hour period between 9:00 p.m. and midnight. The next largest number ran between midnight and 9:00 a.m., and some early-morning lifts indicated that most of these fish entered the trap before 3:00 a.m. Ninety-five per cent of the migrants, during this 2-year period, were taken between 6:00 p.m. and 9:00 a.m. Only occasional stragglers entered the weir during the daylight hours.

Size of spawning fish.—The mean size of all of the northern pike spawners that were taken in 1939 and 1940 was 21.8 inches. The average for the 1,767 northern pike taken during the creel census of

Table 2.—Hourly variation in the number of adult northern pike entering Peterson's Ditch to spawn in 1939 and 1940

[Average number per hour indicated in parentheses]

Year	Total number of spawners	Number captured in time period					
		12 m.-9 a.m.[1]	9 a.m.-12 m.	12 n.-3 p.m.	3 p.m.-6 p.m.	6 p.m.-9 p.m.	9 p.m.-12 m.
1939	378	118 (0.57)	1 (0.01)	8 (0.12)	9 (0.13)	85 (1.23)	157 (2.27)
1940	118	34 (0.25)	1 (0.02)	1 (0.02)	5 (0.11)	38 (0.85)	39 (0.87)
Total	496	152 (0.44)	2 (0.02)	9 (0.08)	14 (0.12)	123 (1.08)	196 (1.72)

[1]Apparently most of the fish taken within this period migrated before 3:00 a.m. (See text.)

the winter of 1936-1937 was 21.2 inches (Eschmeyer, 1937).[3] These figures indicate that the run of spawners in Peterson's ditch was composed of average-sized fish.

No correlation was observed between the average size of either the males or the females and the time of entry into the spawning area. McNamara (1937) said that the average size of males and females increased as the spawning season progressed, but failed to mention whether or not his statement was based on actual measurements. The total lengths of the female northern pike taken in 1939 varied from 19.1 to 37.5 inches and averaged 23.5 inches. The lengths of the males varied from 12.3 to 26.6 inches, with an average of 21.2 inches.

Again in 1940 there was no significant difference in the size of males or females at the beginning and end of the spawning migration. The average total length of the female northern pike was 23.2 inches with a range of 15.1 to 35.9 inches, while that of the males was 19.8 inches, with a range of 12.1 to 26.8 inches. The average total length of the females was about the same in 1939 and 1940, while the males were 1.4 inches shorter in 1940 than in 1939.

Sex ratio.—Both males and females were taken on the first 2 days of the 1939 run on which the fish were examined (Table 1), but the males predominated. Fish of both sexes entered the upstream weir each day of the 1939 run except on April 19 and on the last two days when only males were taken (Table 1). In general, the relative abundance of the males tended to increase as the spawning run progressed. Males comprised 65 per cent of the total number of fish examined in 1939. The sex ratio was 188 males per 100 females. If the same ratio is held to apply to the estimated number of 50 fish that moved upstream before the weir was installed, the total numbers of males and females in the run may be computed as at 280 and 148, respectively. However, 23 of the females that entered the ditches to spawn, were preserved for further study. Consequently, the estimated numbers of fish that were allowed to spawn were 280 males and 125 females (224

[3]Eschmeyer, R. W. 1937. Houghton Lake creel census, winter of 1936-1937. Unpublished report of the Institute for Fisheries Research, No. 417, May 10, 1937.

males per 100 females). With certain minor exceptions the relative abundance of the males tended to increase as the 1939 spawning run progressed.

In 1940, the males seemed to predominate at the beginning of the run; during the first 5 days, 14 males were taken in the weir as compared with 3 females. Females were relatively more abundant during the later days of the run. Males made up 58 per cent of the entire run of northern pike in 1940 (136 males per 100 females). In addition to the fish captured in the weir in Ditch I, 28 northern pike, 13 males and 15 females, were taken in a weir in Ditch V (see text footnote 2) and placed in the area under observation. With these additional fish, the total number of spawners was 146. Eighty-one of these were males and 65 were females (125 males per 100 females). Although observations indicated that sometimes only one male spawns with one female, the majority of the females observed spawning were accompanied by two males, and a few by more than two.

Observations at Houghton Lake do not agree with those of McNamara (1937) who stated that males run upstream first and the females follow later. He did not give any detailed information, however, or offer evidence that all fish running upstream were examined.

Condition of gonads.—Our records indicate that the first northern pike to run upstream were ripe to the extent that milt and eggs dropped from most of the fish as they were picked up. In 1939 all of the males taken in the upstream weir were ripe, as were 90.1 per cent of the females. In 1940, 91.2 per cent of the males and 86 per cent of the females were ripe. It appears, therefore, that the maturation of sperm and eggs of northern pike usually takes place before the fish begin the spawning migration.

Seven fish taken in the weirs in 1940 had clipped dorsal fins, which indicated that they were young that hatched in the ditches in 1939. The average total length of these seven yearling northern pike whose dorsal fins had been removed was 14.6 inches. Four of the fish were ripe males (13.3-15.0 inches, total length), and one was a gravid female (15.7 inches). One male (14.5 inches) was either green or immature, and the sex was not determined for the remaining fish (15.1 inches). Some northern pike, therefore, may be mature at the end of the first year of life. It was not determined whether the eggs and sperm of these fish were viable.

Return of adults to the lake.—A period of 40 days elapsed in 1939 between the time that the first northern pike was taken in the downstream weir on April 21 and the last one had left the ditches on May 30. The majority of the 364 fish, or 93 per cent, returned to the lake between April 25 and May 7. A wide variation was found in the number of days spent in the ditches by the spawning fish. The average[4] number of days spent in the ditches was 18.2 days (range 6

[4]This average is based on only 313 of the 364 downstream migrants because 51 of these 364 fish were either not fin-clipped on their way upstream (the 50 fish that ran upstream the first night were not marked), or an assistant failed to record the marks.

to 50 days). A total of 29 fish died in the ditches. Since two of these had each eaten one marked adult northern pike, it is possible to account for a total of 31 dead northern pike. A number of the northern pike had apparently jumped out of the water onto the ditch banks. Others may have died from the strain of spawning, or from injuries sustained during the spawning act, or during the handling at the weirs. All except about 10 of the northern pike estimated to have gone upstream were accounted for. These 10 fish may have been eaten by other fish, birds, turtles, or may have died and escaped notice. It is also possible that poachers may have captured some of them.

A period of 88 days elapsed in 1940 from the time that the first northern pike was taken in the downstream weir on its return to Houghton Lake, April 24, until the last one had left the ditches on July 20. Fifty-one per cent of the northern pike returned to the lake during the last 7 days of April; 35 per cent returned in May; 13 per cent in June; and 1 per cent in July. The fish on which these percentages were based included the 28 northern pike captured in Ditch V (see text footnote 2). As in 1939, the time the spawners spent in the ditches varied widely. In 1940 the shortest time any one northern pike remained in the ditches was 4 days (April 23-26), the longest period was 90 days (April 22 to July 20), and the average was 23.9 days. Sixteen dead fish were found in the ditches in 1940. Of the number of fish known to have been in the ditches, all but 43 returned or were accounted for. Poachers were known to have been present in 1940, and part of the loss can no doubt be traced to their activities.

Seven small adult northern pike taken in the downstream trap in 1940 on their return to the lake had not been marked. These fish were all small enough to have passed between the slats of the weir in their upstream migration. One of the fish had a clipped dorsal fin, which indicated that it was one of the young northern pike of the 1939 hatch at this place.

Growth of Young Northern Pike

Collections of the young northern pike used for growth determinations were taken in the ditches by seines, minnow traps, and dip nets and from the weir. Collections were made every day, when possible. At times, however, samples could not be obtained by any of the methods mentioned. Since accurate measurements were difficult to make on small, live northern pike, many of them, particularly in the earlier collections, were preserved and measured later in the laboratory. The weekly average lengths of the combined samples from the ditch and from the weir have been employed to estimate the early growth of the northern pike (Tables 3 and 4).

Certain conditions that tended to make the sampling of young northern pike selective as to the size of the fish throw doubt on the reliability of successive average lengths as precise measures of growth. During the earlier part of the sampling period the continual addition of

Table 3.—The weekly average size of young northern pike in Peterson's ditches, 1939

Date	Number of samples	Number in samples	Total length (millimeters) Minimum	Maximum	Average	Increase of average	Average daily increase	Average daily increase by months
May 6	1	32	11	17	13.8	[1].....	.....	.....
May 7-13	7	173	12	30	19.4	5.6	[2]1.2	1.5
May 14-20	6	79	17	42	28.5	9.1	1.3	(May)
May 21-27	4	68	21	77	44.2	15.7	2.2	26 days
May 28-June 3	4	141	36	114	57.6	13.4	1.9	.....
June 4-10	5	92	37	129	105.5	47.9	6.8	3.3
June 11-17	1	4	89	129	106.7	1.2	0.2	(June)
June 18-24	4	52	54	178	127.4	20.0	2.9	30 days
June 25-July 1	2	14	122	215	154.8	27.4	3.9	.....
July 2-8	7	225	54	213	166.2	11.4	1.6	0.4
July 9-15	7	190	94	229	162.7	—3.5	—0.5	(July)
July 16-22	5	101	98	219	167.6	4.9	0.7	23 days
July 23	1	16	107	191	160.4	[1]—7.2	[2]—1.6	.....
Total	54	1,187	.....	.....	.....	....	....	.....

[1]Less than 1 week. [2]4½ days.

newly-hatched fish reduced the average differences to less than the probable growth of individual fish. Samples taken from the ditch were affected most severely by this source of error. The average lengths of the earlier collections from the weir, on the other hand, may have been somewhat high because of the tendency of young northern pike to move downstream only after the attainment of a certain minimum size. Very few fish less than 20 millimeters long were taken in the weirs at periods when smaller fish were extremely abundant in the ditches. Cannibalism also tended to increase the average length of samples from the weir since the smaller fish deprived of their natural protective cover and confined in close quarters, frequently were eaten by the larger individuals in the trap. The average lengths of samples from both the ditches and the weir may have been too small in the latter

Table 4.—The weekly average size of young northern pike in Peterson's ditches, 1940

Date	Number of samples	Number in samples	Total length (millimeters) Minimum	Maximum	Average	Increase of average	Average daily increase	Average daily increase by months
May 4	1	14	8.5	12	10.1	[1].....	.....	.....
May 5-11	3	35	10.0	16	13.3	3.2	[3]0.7	0.6
May 12-18	2	52	17.0	22	19.1	5.8	0.8	(May)
May 19-25	3	53	17.0	31	23.1	4.0	0.6	28 days
May 26-June 1	2	15	22.0	32	27.3	4.2	0.6	.....
June 2-8	4	70	28.0	52	39.3	12.0	1.7	2.1
June 9-15	3	139	37.0	85	50.9	11.6	1.7	(June)
June 16-22	5	52	41.0	100	63.0	12.1	1.7	30 days
June 23-29	5	6	64.0	134	88.0	25.0	3.4	.....
June 30-July 6	6	36	48.0	126	102.8	14.8	2.1	.....
July 7-13	7	17	92.0	136	111.5	8.7	1.2	1.3
July 14-20	5	56	78.0	177	114.8	3.3	0.5	(July)
July 21-27	3	15	97.0	166	124.1	9.3	1.3	27 days
August 22-24	2	3	190.0	227	208.7	[2]84.6	[4]2.8	.....
Total	51	563	.....	.....	.....	....	....	.....

[1]Less than 1 week. [2]2 days (Aug. 22 and 24). [3]4½ days. [4]30½ days.

ERRATUM: Vol.71,pp.159-160

Page 159, first paragraph, fifth line, starting with "(
d cloudy weather," to the fourth line from the bottom of p
ding with "they spend in the pond," should start a new par
raph to follow the third paragraph ending "per day in July.
n page 160.

part of the sampling period because of the earlier migration of the individuals with the more precocious growth.[5] Data were not available for the evaluation of the amount of error introduced by these sources of selection. Fortunately, some of the sources tended to compensate each other. Nevertheless, it is believed that the estimates of growth provided by the data of Tables 3 and 4 should be considered minimal.

The weekly average sizes of the young northern pike taken in the ditches during 1939 are recorded in Table 3. These averages fluctuate a great deal, probably because of inadequate samples, therefore discussion is based mainly on the average daily increase in size in the different months. Cool and cloudy weather with frequent rains may account in part for the slow growth during May. The average length of young northern pike increased at the rate of 1.3 millimeters per day during the 85 days from the time of hatching on May 4, until July 27, the last day on which an adequate sample was taken. Only three northern pike fingerlings were taken after July 27; one of them was caught on August 22 and the other two on August 24. The largest northern pike fingerling taken from the ditches in 1940 was caught on August 22, and had a total length of 8.9 inches.

Fifty young northern pike were taken with a seine on June 17 in Ditch VII (see Fig. 1) which was not under observation in 1940. The average total length of these fish was 100.7 millimeters; the length varied from 69 to 139 millimeters. They averaged just 33 millimeters larger than young taken on the same date in the ditches that were under observation (Ditches I-IV). One possible explanation for this excellent growth is that Ditch V usually contains water the year around and may therefore have a better food supply. The fact that minnows migrate up this ditch from the Muskegon River is particularly important. This more or less permanent stock of forage fish was supplemented in May, 1940, by several thousand minnows 2 to 4 inches long that escaped from the tanks of a commercial minnow dealer.

One hundred eighty-five northern pike with an average total length of 20.0 millimeters were taken from Ditches I-IV and placed in an experimental minnow pond at the Drayton Plains Hatchery on May 11, 1939. This pond was stocked liberally with minnows of all sizes. On October 19, when the pond was drained, 10 northern pike were removed. The total length of these fish ranged from 11.25 inches to 14.25 inches, and averaged 12.54 inches. Their average daily growth was 1.85 millimeters during the 161 days they spent in the pond. Measurements were made of 1,187 young northern pike. Advanced fry, probably representing successive hatches, appeared in the daily collections from the ditches as late as May 13. Others possibly may have

[5]The relationship between size and time of migration was not clear-cut. Although few fish migrated at a length of less than 20 millimeters, large numbers remained in the ditches until they had become much larger. Once all the young northern pike had passed the length of 20 millimeters, little correlation could be observed between length and the tendency to move downstream.

hatched after this date, but none were taken in any of our samples. During May the average size of young northern pike increased on the average of 1.5 millimeters per day. The increases were irregular in June, but averaged 3.3 millimeters per day. Growth appears to have declined in July; the increase in size averaged just 0.4 millimeters per day. Certain of the irregularities in the data are no doubt traceable to the small numbers of fish in the samples. A great divergence existed between the minimum and the maximum lengths of young northern pike throughout the period of sampling. With few exceptions (when the samples were small), the minimum and maximum sizes of young fish increased from week to week along with the average size.

In 1939 the average length of the young northern pike taken in the ditches and in the weir increased at the rate of 1.8 millimeters per day during the 82 days between the estimated time of first[6] hatching on May 3, until the ditches dried up on July 23.

The maximum length attained by any young northern pike in the ditches during the 1939 season was 9 inches. This fish was taken on July 10 and was probably not more than 69 days old. Its daily average rate of growth may be estimated therefore as 3.2 millimeters.

The average daily increase in the length of young northern pike during May, 1940 (28 days) was 0.6 millimeters per day (Table 4). This average was 2.1 millimeters per day during June and 1.3 millimeters per day in July.

The remarkably rapid growth made by the young northern pike is approached by only one other fresh-water fish for which data are available, the northern long-nosed gar, *Lepisosteus osseus*, (Hubbs, 1921).

Migration of Young Northern Pike

All of the young northern pike that migrated from Peterson's ditches in 1939 and 1940 were taken in a weir, counted and then were released in Houghton Lake. Samples of the young were measured before the release. More young fish moved downstream from the marshes to the lake on clear, bright days than on cloudy days. It was observed that the young pike drifted along, either head or tail first or across the current, just beneath the surface of the water.

The first free-swimming fry were observed on the afternoon of May 5, 1939. These young northern pike were all advanced fry with remnants of the yolk sac attached. The young fish were found just below the surface of the water and when frightened darted into the weeds or dropped to the bottom. Young northern pike appeared to be much more active, and remained nearer the surface of the water on bright, sunny days than on cloudy days.

The first northern pike fingerlings moved into Houghton Lake from the ditches on May 12, 1939, approximately 10 days after hatching (see text footnote 6). At this time their average total length was 19

[6]The first fry observed on May 5 were estimated to have hatched about 2 days earlier.

millimeters. Of the total number of fish that were taken in the weir in the 1939 season, 85.4 per cent migrated during the last 20 days of May, 8.6 per cent in June and 6.0 per cent in July (Table 5).

The first newly-hatched fry in 1940 were found on May 4, each hanging to a plant by a thread from the adhesive organ. The first free-swimming fry were observed on May 7. During the next few weeks many fry and fingerlings were observed, and they appeared to be as numerous as in 1939, when many more adults spawned in this area.

In 1940 the first young northern pike were taken in the downstream weir on May 25, 22 days after the first fry were observed in the ditches. This interval is in contrast with 1939, when the first young northern pike moved down 10 days after hatching. At the time of the first 1940 migration (May 25), the total length of the fish averaged 23 millimeters. In the 1940 season, 24.9 per cent of the total run of fish entered the lake in the last 7 days in May (May 25-31). The majority

Table 5.—The number of young northern pike migrating from Peterson's ditches into Houghton Lake in 1939 and 1940, by monthly periods

Month	1939		1940	
	Number taken	Percentage of total	Number taken	Percentage of total
May	[1]6,184	85.4	[2]372	24.9
June	621	8.6	999	66.8
July	434	6.0	121	8.1
August	.....	.....	3	0.2
Total	7,239	100.0	1,495	100.0

[1]May 12-31 (20 days). [2]May 25-31 (7 days).

(66.8 per cent) entered the lake in June, 8.1 per cent in July and 0.2 per cent (3 fish) in August. Altogether, 90.9 per cent of the total number of young fish migrated to the lake during the first 26 days of the run (May 25 to June 19).

It appears that the run of young northern pike was about 12 days later in 1940 than in 1939. The only explanation that can be suggested is that there were more cloudy and cold days during May in 1940 than in 1939. In the 1940 season, only 24.9 per cent of the total run of fish entered the lake from the ditches during May (7 days), as compared to the 85.4 per cent that moved into the lake during the last 20 days in May, 1939.

Total Number of Young Northern Pike Migrating

Altogether, 7,239 young northern pike returned to the lake in 1939 (Table 5). This number[7] represents the total production resulting from the spawning of 125 females and 280 males.

During the 1940 season, 1,495 young northern pike moved to Hough-

[7]The number of migrating young no doubt would have been slightly higher in each year had not samples been taken from the ditches for the study of growth. The numbers given here include preserved fish that were captured in the weirs. Preserved fish that had been taken in the ditches were not added since there was no sound basis on which to estimate the percentage that might have survived to migrate downstream.

ton Lake from the marshes (Table 5). The total represents the production resulting from the spawning of 65 females and 81 males (see text footnote 7). It is not believed that the smaller number of spawners in 1940 accounted for the low production as compared with 1939, since the examination of the ditches shortly after hatching indicated young northern pike to be as abundant in 1940 as at the corresponding period of the preceding year.

The greater abundance of minnows and small perch in the ditches in 1940 doubtless contributed to the lower production in that year. In 1939, minnows and small yellow perch (2 to 4 inches long) started to run up the ditches at about the time the northern pike fry were hatching. The minnows and yellow perch were allowed to enter the ditch for only 1 day. Samples of the fish were taken at intervals and preserved for a later stomach analysis. Cursory examination of a few of the yellow perch revealed that some of them had eaten small northern pike. Yellow perch and minnows were not prevented from running upstream in 1940 because it was decided that to block off the run would upset natural conditions. Samples of the yellow perch and minnows were collected and preserved throughout the summer but as yet their stomachs have not been examined. However, there is little doubt that the yellow perch were partially responsible for the reduced production of northern pike in the ditches in 1940.

Acknowledgments

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Summary

1. An investigation was begun on the spawning activities and the early life history of the northern pike in the marshes and drainage ditches flowing into the north bay of Houghton Lake in the spring of 1939 and was continued through that summer and the spring and summer of 1940.

2. Practically all migrating northern pike young and adults were captured in weirs.

3. Northern pike spawners usually ascend the ditches in the early spring as soon as the flow of water from the ditches opens a hole between the ice cover of the lake and the lake bottom.

4. In 1939, the spawning migration covered a period of 24 days

(April 2 to April 25). In 1940 the fish entered the spawning grounds over a period of 15 days (April 9 to April 23).

5. A total of 428 northern pike entered the ditches in 1939 as compared with 118 in 1940. The sex ratio was 188 males per 100 females in 1939 and 136 males per 100 females in 1940.

6. The average size of neither the males nor the females varied according to the time of entry into the spawning run. The average total length of female northern pike in 1939 was 23.5 inches while the males averaged 21.2 inches. In 1940 the female northern pike averaged 23.2 inches, total length, and the males averaged 19.8 inches.

7. No correlation could be found between the temperature of the water in the ditches on different days and the number of fish that ascended.

8. Ninety-five per cent of the adult northern pike entered the spawning area between 6:00 p.m. and 9:00 a.m. The largest number of fish entered the weir in the 3-hour period between 9:00 p.m. and midnight. Only occasional stragglers moved upstream during the daytime.

9. The relative abundance of the males tended to increase as the 1939 spawning run progressed. The change of the sex ratio was without definite trend in 1940 although the females were somewhat more abundant toward the middle of the spawning run than at the beginning.

10. Observations indicated that the maturation of sperm and eggs of northern pike usually takes place before the fish begin the spawning migration.

11. Seven yearling northern pike that had been fin-clipped at Peterson's ditches in 1939 were captured in the up stream weir in 1940. Some individuals, therefore, are mature at the end of the first year of life.

12. The average daily increase in the length of young northern pike in 1939 was 1.8 millimeters per day during the first 82 days after hatching. In 1940 the daily increase averaged 1.3 millimeters per day during the first 85 days after hatching.

13. In 1939 a total of 7,239 young northern pike moved downstream from the ditches. In 1940 the number was only 1,495.

14. In 1939 and 1940 small minnows and yellow perch began to run up the ditches at about the time the northern pike fry were hatching. Cursory examination of a few of the yellow perch revealed that a few of them had eaten small northern pike. The greater abundance of minnows and yellow perch in the ditches in 1940 doubtless contributed to the lower production in that year.

15. The first northern pike fingerlings moved into Houghton Lake

from the ditches on May 12, 1939, approximately 10 days after hatching. In 1940, the first fry were taken in the downstream weir on May 25, just 22 days after hatching. This apparent delay of 12 days in the 1940 run was probably due to the colder weather in May of 1940 as compared with May of 1939.

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BOTTOM ORGANISMS IN FERTILIZED AND UNFERTILIZED FISH PONDS IN ALABAMA[1]

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ABSTRACT

A study was made of two experimental fish ponds located at the Agricultural Experiment Station at Auburn, Alabama. Bottom samples were taken from June to November, 1940, in a 1.5-acre fertilized pond and in a 1.8-acre unfertilized pond. Two methods of sampling were used, the Petersen dredge method and the stove-pipe method. The latter method consistently gave a better quantitative sample than the former. The fertilized pond produced 382.9 pounds of fish per acre; the unfertilized pond produced 147.1 pounds per acre. The area of the fertilized pond was reduced two-thirds of its original size during the fall drought, causing a tremendous concentration of bottom organisms. The weight of bottom organisms in the fertilized pond during a 5-month period was 68.27 milligrams of dry organic matter per square foot, and for the unfertilized pond the average was 19.62 milligrams. The plankton samples for the same period contained an average weight of 5.81 milligrams per liter in the fertilized pond, and an average of 2.54 milligrams per liter in the unfertilized pond. Routine stomach analyses of bluegills from both ponds showed that the fish in the fertilized pond had plenty of insects throughout the period, and that in the unfertilized pond they had sufficient insects in June only. The fertilizer more than doubled the weight of fish, plankton and bottom organisms in the fertilized pond as compared with those in the unfertilized pond.

INTRODUCTION

Many attempts have been made to show the relationship between total bottom fauna and fish production. Numerous workers have taken bottom samples in streams and lakes and have made qualitative and quantitative counts in an effort to determine stocking policies, or to find out if there is a direct relationship between the average weight of bottom organisms per square foot or square meter and the pounds of fish in a mile of stream or in an acre of water (Richardson, 1921; Surber, 1937; Davis, 1938; Tarzwell, 1938; and Thorpe and Grosvenor, 1940). Tarzwell, and Thorpe and Grosvenor gave the results of various stream improvement devices which seemed to increase population of bottom organisms and the production of fish.

For centuries man has tried by various ways to increase the fish production in ponds and small lakes. Many fertilizers have been tried and today fish-culturists generally accept the idea that fertilizing fish ponds is a sound practice. Davis and Wiebe (1930), Hogan (1933), and Meehean (1933), all reported favorably on the use of various fertilizers in hatchery ponds. Swingle and Smith (1939) found that a

[1]Published with the approval of the Director.

balanced inorganic fertilizer greatly increased fish production in ponds, and the fertilizer mixture recommended by them is being used extensively in the southeastern States.

None of the literature cited has considered the possible relationship between bottom organism production and fish production in ponds. Meehean (1936), using cottonseed meal as a fertilizer, found ". . . a relationship between the total weight of fish produced and the total weight of organisms when the weight of organisms is small enough to become a limiting factor." He obtained a production of 48 pounds of bass per acre when the weight of organisms was 5 grams per square meter. As the weight of organisms increased from 5 grams to 9 grams per square meter, the weight of the bass per acre increased from 48 pounds to 105 pounds. When the weight of bottom organisms increased from 9 grams to a maximum of 18 grams, the weight of bass increased very little.

Experiments have been conducted at the Alabama Agricultural Experiment Station, in fertilized and unfertilized fish ponds during the last 7 years, and data on plankton and fish production have been collected annually. It was believed that some information relative to the interrelationship between the production of fish, plankton and bottom organisms could be obtained if, in addition to the usual fish and plankton production studies, bottom samples were obtained from a fertilized and an unfertilized pond.

Materials and Methods

The unfertilized pond had an area of 1.8 acres and a maximum depth of 10 feet and was supplied by a small inlet stream that kept the pond full. The pond was constructed in 1934, and since 1935 it had been supporting approximately 150 pounds of fish per acre. It had never been fertilized, and there was a ring of *Najas guadalupensis* around the edges in water up to 3½ feet deep. This weed was kept under control by raking.

The fertilized pond had an area of 1.5 acres and a maximum depth of 6 feet. It was a terrace-water pond, and the small, wet-weather stream became dry during periods of drought. Prolonged rainless periods caused considerable shrinkage in the area of the pond. This pond was constructed in 1938, and it had been fertilized each year with inorganic fertilizers to increase fish production, and had been supporting approximately 350 pounds of fish per acre. No higher aquatic plants have been in this pond.

For this experiment both ponds were stocked with bluegill bream (*Lepomis macrochirus* Raf.) in February, 1940, and with largemouth black bass (*Huro salmoides* Lacépède) fry in May, 1940. The stocking rates were those recommended by Swingle and Smith (1938) for a fertilized and an unfertilized pond.

Aquatic biologists generally agree that present standard methods of bottom sampling are not accurate. In an effort to secure representa-

tive bottom samples two methods were employed, the Petersen dredge method and the stove-pipe method. The first samples were taken on June 10, and the next group on June 17. The remaining samples were taken at 2-week intervals, the last on November 2. The depths at which samples were taken were: 6 inches, 18 inches, 3 feet, 5 feet and 9 feet. Both ponds were sampled the same day, and six stove-pipe samples and two dredge samples were taken at each of the three shallower depths. Only dredge samples were taken in water deeper than 3 feet. Dredge samples were not taken after September 9 in the 6-inch, 18-inch and 3-foot depths, the depths sampled by the stove-pipe method. The dredge samples in the shallower depths were discontinued because the stove-pipe samples consistently gave two to three times higher quantitative results.

Two sections of 7-inch diameter stove pipe were used to take the stove pipe samples and only one section of pipe was used in sampling depths up to 18 inches. The two sections were joined together to obtain the 3-foot samples. A measuring pole was used to locate the depth of water at which each sample was taken. After the sampling location had been selected the stove pipe was pushed 2 to 3 inches into the bottom mud. A wooden paddle was then used to agitate the contents of the pipe, taking care to loosen all sediment possible. When a uniform column of mud, detritus and water appeared in the stove pipe a subsample was dipped out into a glass jar. The amount of subsample removed was on the basis of 1 liter per foot of depth of water at the location sampled, and represented the material from 1/27 square foot of bottom surface.

The dredge samples were taken with the standard Petersen dredge square-foot sampler that holds nearly 2 gallons when closed. A row boat was used in taking the dredge samples. The desired depth to be sampled was found with the measuring cane. The entire contents of each dredge sample was emptied into a 2½-gallon galvanized pail, thoroughly stirred and a subsample removed for examination. This subsample represented the material from ¼ square foot of bottom surface.

In order to obtain weights comparable with those of the plankton samples, the weight of dry organic matter present in the bottom organisms was determined. After the organisms had been separated to order (to family in the Hemiptera, Coleoptera and Diptera) they were placed in crucibles, oven-dried, weighed, incinerated and weighed again. The difference between the dry weight and the incinerated weight represented the weight of dry organic matter in the sample; this difference is hereafter referred to as the "weight of bottom organisms."

A few fish were captured with seines in June, July, September and November and brought into the laboratory for measurements and stomach analyses. The organisms that occurred most frequently and that comprised the greatest volume in each stomach were determined.

Relationship Between Production of Fish, Plankton and Bottom Organisms

The unfertilized pond was drained on November 25, and all the fish were counted and weighed. It produced 264.9 pounds of fish on 1.8 acres, or 147.1 pounds to the acre. The fertilized pond was drained on November 11, and produced 459.5 pounds of fish on an average area of 1.2 acres, or 382.9 pounds to the acre. The fish production in the fertilized pond was 2.6 times as great as that in the unfertilized pond.

The plankton samples covering the same period as the bottom samples contained an average weight of 5.81 milligrams per liter in the fertilized pond and 2.54 milligrams in the unfertilized pond, averaging 2.3 times as much in the fertilized as in the unfertilized pond.

The average weight of organisms in the fertilized pond for a period of 22 weeks was 68.27 milligrams per square foot, and in the unfertilized pond 19.62 milligrams; 3.48 times as great in the fertilized as in the unfertilized pond. The seasonal distribution of the weight of bottom organisms and plankton for both ponds during the 5-month period is shown in Figure 1. The average for the fertilized pond is higher than it should be because the area of the pond dropped from 1.4 acres on September 1 to 0.5 acres on November 2, thus concentrating the organisms. The concentration of bottom organisms increased as the pond area decreased. On September 9 the average weight of the organisms was 32.00 milligrams per square foot, and on November 2 it was 230.62 milligrams.

In order to determine if part of the increase in number of organisms was natural, samples were taken from another pond at the experiment station that had been fertilized at the same rate and which had shown no appreciable decrease in size from drought. The average weight of organisms on November 3 was 91.47 milligrams per square foot. In the unfertilized pond, which had a constant area, on the same date the weight of organisms was 12.29 milligrams; and there had been a gradual decrease since the middle of August. This second fertilized pond also produced about 400 pounds of fish per acre, in comparison with the 150 pounds per acre produced in the unfertilized pond. Monthly stomach examinations of the bluegills from both fertilized ponds, and from the unfertilized pond, revealed that the fish in the two fertilized ponds fed largely on insects throughout the 5-month period during which bottom samples were collected; whereas in the unfertilized pond the principle food of the bluegills was the aquatic plant *Najas*, and June was the only month during which a preponderance of insect material was eaten. Thus it appears that to increase fish production greatly it is necessary that the weight of bottom insects per square foot increase rapidly as the growing season progresses. The gradual upturn in abundance of bottom fauna during the fall in fertilized ponds is due largely to the great increase in number of phantom midge larvae (Chaoborinae).

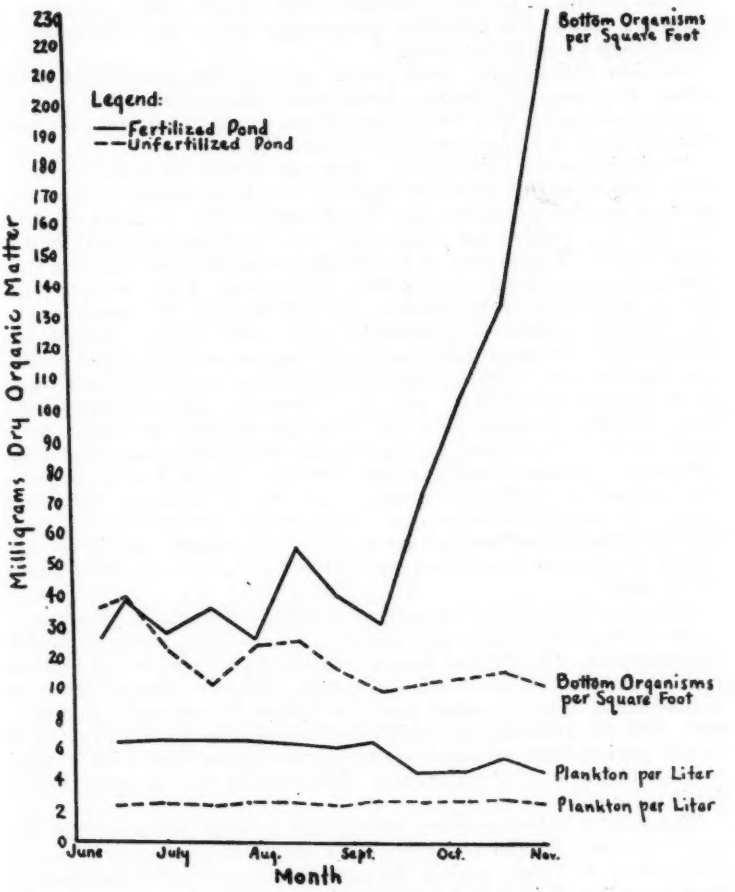

Figure 1.—Seasonal variations in the weight of plankton and bottom organisms in fertilized and unfertilized ponds.

Abundance of Bottom Organisms

The average numbers and weights per square foot of the more important groups of bottom organisms found in both ponds are given in Tables 1 and 2. The following paragraphs give a brief discussion of each group listed in the tables.

Leeches (Hirudinea) were found only in the unfertilized pond, where they occurred during June, July and August. The average number per square foot for this period was less than 1.0, and they were found only in the 6-inch and 18-inch samples.

Tubificid worms (Tubificidae) were one of the few forms found in both ponds during the entire period. In the unfertilized pond the average number per square foot was 62, and in the fertilized pond 46. The average weights per square foot were 2.40 and 1.99 milligrams, respectively. The number of Tubificidae per square foot has been used frequently as an index of pollution. Richardson (1928) reported that five or six species of Tubificidae were of value for this purpose, and that *Tubifex tubifex* had unusually good index value. Wright and Tidd (1933) discussed pollution on the basis of number of Tubificidae per square meter. "Three degrees of pollution were recognized, based on the number of tubificids per square meter, as follows: Light pollution, 100-999; moderate pollution, 1,000-5,000; heavy pollution, more than 5,000." According to this classification both ponds had light pollution. It would seem that any fertilizer should tend to increase the number of tubificids; however, the use of inorganic fertilizers seemed to decrease their number. The greatest concentration of these worms in the unfertilized pond was at the 3-foot depth, and in the fertilized pond about equal numbers occurred in the 6-inch, 18-inch and 3-foot samples.

An unknown species of aquatic earthworm (Oligochaeta) was found in the unfertilized pond a majority of the times it was sampled, which was approximately 10 times larger than the *Tubifex* worm, and whenever molested rolled itself into spiral coils around a piece of debris or a small stick. They occurred mostly in 6-inch, 18-inch and 3-foot samples, with the greatest concentration at the 6-inch depth. For the 5-month period they averaged seven to the square foot with a total average weight of 2.19 milligrams. This species did not occur in the fertilized pond.

Water-mites (Hydracarina) were found in both ponds during the entire period. In the fertilized pond they did not occur in water deeper than 18 inches; and in the unfertilized pond small numbers of them were found in 3-foot water, with the greatest concentration in shallower water. The fertilized pond averaged 20 watér-mites to the square foot, and the unfertilized pond averaged 7. The average weights were 1.99 and 0.91 milligrams, respectively.

Mayfly nymphs (Ephemerida) were much more numerous in the fertilzed pond than in the unfertilized pond. Nymphs were found every time the fertilized pond was sampled and the average number of

Table 1.—Average number per square foot and weight in milligrams of dry organic matter per square foot of the more important bottom organisms in an unfertilized pond

Organisms	June 10		June 17		July 1		July 15		July 29		Aug. 12		Aug. 26		Sept. 9		Sept. 23		Oct. 5		Oct. 19		Nov. 2	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Leeches	2	3.78	90	.....	..	.....	..	.....	11	0.70	1	0.36	1	0.36	..	.....	..	.....	..	.....	..	.....	..	.....
Tubificids	45	2.61	..	4.54	84	1.68	84	2.60	86	3.44	75	3.76	73	3.66	34	1.02	54	1.62	42	1.25	33	0.99	53	1.60
Annelids	50	10.88	..	.....	7	3.08	..	.....	..	.....	8	3.51	5	2.07	5	1.84	3	2.60	..	.....	..	.....	5	2.26
Hydracarina	9	0.92	13	1.34	8	0.86	22	2.16	3	0.26	15	1.48	5	0.54	9	0.86	3	0.32	5	0.74	4	0.44	10	1.00
Ephemerida	9	5.40	2	1.08	1	0.14	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....
Anisoptera	..	.....	..	.....	..	.....	..	.....	..	.....	1	7.30	1	4.27	1	1.70	..	.....	..	.....	1	1.90	..	.....
Corixidae	7	4.50	5	6.48	5	1.75	4	1.15	2	1.44	3	0.92	..	.....	2	0.68	..	.....	..	.....	..	.....	..	.....
Haliplidae	2	3.26	4	6.52	1	1.70	..	.....	1	2.90	1	2.40	..	.....	..	.....	..	.....	..	.....	2	5.23	..	.....
Hydrophilidae	..	.....	2	5.40	..	.....	..	.....	..	.....	1	0.80	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....
Trichoptera	..	.....	..	.....	1	saved	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	4	0.61
Chaoborinae	1	0.20	..	.....	9	1.97	1	0.32	1	0.28	2	0.20	3	0.36	8	0.59	27	2.45	14	1.32	23	2.07	19	1.72
Tabanidae	..	.....	..	.....	1	0.36	2	0.72	3	1.23	1	1.15	3	1.28	..	.....	5	2.30	1	5.90	2	2.00	..	.....
Chironomidae	29	5.75	70	9.95	38	5.61	20	2.14	34	8.40	4	0.40	13	1.13	2	0.11	23	1.18	14	0.93	10	1.45	16	1.32
Ceratopogonidae	13	2.77	24	5.32	15	3.08	34	2.06	36	4.71	64	2.56	43	1.34	51	1.54	67	2.02	89	2.68	44	1.31	80	3.65

Table 2.—Average number per square foot and weight in milligrams of dry organic matter per square foot of the more important bottom organisms in a fertilized pond

Organisms	June 10		June 17		July 1		July 15		July 29		Aug. 12		Aug. 26		Sept. 9		Sept. 23		Oct. 5		Oct. 19		Nov. 2	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Tubificidæ	86	0.86	27	0.27	84	4.19	54	1.62	15	0.59	14	0.68	50	2.58	14	0.41	48	1.43	25	0.75	62	1.85	81	2.43
Hydracarina	5	0.45	19	1.85	5	0.41	9	0.90	16	1.58	24	2.38	42	4.18	8	0.80	39	3.93	13	1.25	27	2.73	34	3.43
Ephemerida	9	2.25	5	0.45	51	7.29	36	5.04	44	4.40	92	11.07	84	8.35	14	1.08	22	1.72	32	1.26	11	0.32	9	0.90
Anisoptera	..	.....	..	.....	2	2.25	2	2.93	..	.....	4	16.00	1	5.71	..	.....	2	9.11	..	.....	2	6.75	..	.....
Corixidae	7	0.34	18	12.16	2	0.16	2	0.72	1	1.00	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....
Hydrophilidae	5	7.15	2	5.63	3	2.63	..	.....	1	0.81	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....	..	.....
Trichoptera	..	.....	..	.....	2	0.90	2	0.23	4	3.50	5	2.57	4	2.45	..	.....	..	.....	2	1.80	2	0.08	..	.....
Chaoborinae	1	0.25	..	.....	..	.....	..	.....	..	.....	6	0.66	22	3.08	297	20.79	433	38.97	839	75.49	681	61.29	939	84.51
Tabanidae	..	.....	..	.....	..	.....	7	8.37	2	4.86	4	9.87	1	0.63	..	.....	..	.....	..	.....	..	.....	..	.....
Chironomidae	94	9.18	126	17.38	89	4.44	221	13.78	61	7.54	105	6.29	77	6.01	244	15.33	196	9.28	125	17.42	261	88.85	674	128.12
Ceratopogonidae	20	0.41	7	0.14	16	0.80	43	2.57	60	1.80	45	2.57	63	2.53	37	1.49	102	6.12	65	5.83	44	4.80	51	11.22

nymphs for the 5-month period was 34 per square foot and the total average weight was 3.68 milligrams. In the unfertilized pond, mayfly nymphs were not found after July 1. For the first three samplings the average number was three per square foot with a weight of 2.21 milligrams. In both ponds practically the only form was *Caenis* sp. and no nymphs were found in water deeper than 18 inches.

Dragonfly nymphs (Anisoptera) were found at very irregular intervals throughout the summer in both ponds in the 6- and 18-inch samples. None were recovered in the unfertilized pond before August 12, and from then until November 2 the average number was 0.6 per square foot, with a weight of 2.21 milligrams. In the fertilized pond the first nymph was recovered on July 1 and the average for the entire period was 1.0 per square foot with an average weight of 3.56 milligrams.

Water-boatmen (Corixidae) were found in the greatest numbers during June and July, but as summer progressed their numbers gradually decreased, and they finally disappeared from the ponds. The unfertilized pond produced an average of 3.5 individuals per square foot until September 9; after that they were not found. In the fertilized pond they were not found after July 29, and for the five samplings the water-boatmen had an average of six to the square foot with a weight of 2.85 milligrams. None was found in water deeper than 18 inches.

Crawling water-beetles (Haliplidae) were found only in the unfertilized pond. A few larvae were recovered, but the majority of the specimens were adult *Peltodytes sexmaculatus* Roberts and *Haliplus triopsis* Say. These beetles were found only in the 6-inch samples.

Water-scavenger beetle larvae (Hydrophilidae), *Berosus* sp., occurred most abundantly during June and July. In the unfertilized pond, larvae were found only in the 6-inch samples taken on June 17 and August 12, when the average numbers per square foot were 2.0 and 1.0, respectively, and the weights 5.40 and 0.80 milligrams. In the fertilized pond, water-scavenger beetle larvae were found in gradually decreasing numbers through July 29. The average number per square foot for this period was 2.0, and the total average weight 3.24 milligrams. They occurred only in the 6- and 18-inch samples.

Caddisfly larvae (Trichoptera) were much more common in the fertilized than in the unfertilized pond. The only larva recovered in the unfertilized pond before November 2, when there was an average of 4.0 worms per square foot, was on July 1. In the fertilized pond the greatest concentration was in July and August. For the 5-month period the average number of caddisfly larvae was 1.7 per square foot, and the average weight 0.96 milligrams. The most common forms encountered were *Oecetis* sp. and *Orthotrichia* sp. These larvae were also found only in the 6- and 18-inch samples.

Phantom midge larvae (Chaoborinae) were found in ever-increasing numbers in the fertilized pond beginning on August 12, and in less

than a month they became the dominant organisms in the pond. With the exception of the samples taken June 10, not a single phantom midge larva had been recovered until the invasion began in August. The average number of larvae was 460 per square foot for the last seven times the pond was sampled, and the average weight was 36.30 milligrams. In the unfertilized pond the phantom midge population showed no decided upturn in the fall, but remained rather constant for the whole period of time. The 5-month average was nine larvae per square foot, and the average weight was 0.96 milligrams. They were found largely in water 3 feet deep or deeper.

Horse-fly larvae (Tabanidae), *Chrysops* sp., were found more frequently in the unfertilized pond, and occurred in the fertilized pond only during the middle of the summer. In the unfertilized pond the 5-month average was 1.8 per square foot, and the total average weight 1.49 milligrams. Horse-fly larvae were found only in July and August in the fertilized pond, and the average during this time was three larvae per square foot, with a total average weight of 5.93 milligrams. Tabanids were found in the 6-inch, 18-inch and 3-foot depths.

Midge larvae (Chironomidae) were the most abundant bottom organism in both ponds during most of the season. The average weight of of midge larvae in the fertilized pond follows very closely the curve for the average weight of all bottom organisms in the pond (compare data in Tables 1 and 2, Figure 1). The average weight of midge larvae per square foot in the fertilized pond was nearly nine times as great as that in the unfertilized pond. The weights were 26.96 and 3.26 milligrams, respectively, and the average numbers of larvae were 189 and 23. There was a wide variety of species in both ponds. One

Table 3.—Stomach analyses of bluegills removed from unfertilized pond

Food	June		July		September		November		Season totals	
	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism
Algae	....	....	....	....	0.0	16.6	....	....	0.0	5.0
Najas	0.0	33.3	100.0	100.0	83.9	100.0	0.0	60.0	40.0	70.0
Zooplankton	0.0	16.6	....	....	....	....	....	....	0.0	5.0
Hydracarina	0.0	33.3	....	....	....	....	....	....	0.0	10.0
Anisoptera	16.6	16.6	....	....	16.6	16.6	20.0	40.0	15.0	20.0
Zygoptera	....	....	....	....	....	....	0.0	20.0	0.0	5.0
Corixidae	0.0	16.6	....	....	0.0	16.6	0.0	60.0	0.0	25.0
Trichoptera	16.7	66.6	....	....	....	....	....	....	5.0	20.0
Chaoborinae	....	....	....	....	0.0	16.6	....	....	0.0	5.0
Chironomidae	50.0	66.6	0.0	33.3	0.0	16.6	....	....	15.0	30.0
Ceratopogonidae	0.0	33.3	....	....	....	....	....	....	0.0	10.0
Snails	....	....	0.0	33.3	....	....	....	....	0.0	5.0
Clams	16.7	16.7	....	....	....	....	....	....	0.0	5.0
Fish	0.0	16.6	....	....	0.0	33.3	80.0	100.0	20.0	40.0

Table 4.—Stomach analyses of bluegills removed from fertilized pond

Food	June		July		September		November		Season totals	
	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism	Percentage of stomachs ranking first in relative volume	Percentage of stomachs containing organism
Algae	....	....	....	....	44.5	55.5	....	....	12.1	15.1
Zooplankton	80.0	90.0	0.0	100.0	11.1	55.5	....	....	27.3	81.8
Hydracarina	0.0	20.0	0.0	20.0	....	....	....	....	0.0	9.0
Ephemerida	0.0	10.0	40.0	40.0	....	....	....	....	6.0	9.0
Anisoptera	10.0	10.0	0.0	20.0	11.1	11.1	11.1	22.2	9.0	15.1
Corixidae	0.0	40.0	0.0	40.0	....	....	....	....	0.0	18.1
Coleoptera	....	....	....	....	0.0	11.1	....	....	0.0	3.0
Trichoptera	10.0	40.0	0.0	40.0	....	....	....	....	3.0	18.1
Chironomidae	0.0	50.0	60.0	100.0	0.0	66.6	66.7	77.7	27.3	69.6
Ceratopogonidae	0.0	10.0	0.0	40.0	....	....	....	....	0.0	9.0
Snails	0.0	20.0	....	....	....	....	....	....	0.0	6.0
Tadpoles	....	....	....	....	33.3	44.4	22.2	33.3	15.3	21.2

blood-red species (*Chironomous* sp.) was found only in water 3 feet deep or deeper, and it frequently reached a length of 1½ inches. During the middle of the summer more than half of the midge population of the unfertilized pond belonged to the predaceous subfamily Tanypodinae. It is possible that the presence of so many tanypodine and ceratopogonid larvae (predaceous on other dipterous larvae: Johansen, 1936; Thomsen, 1937) kept the average number of vegetation-feeding chironomid larvae reduced to a minimum. No Tanypodinae were found in the fertilized pond. Chironomid larvae were found at all depths; the greatest concentrations occurred in the 6- and 18-inch samples.

Ceratopogonid larvae (Ceratopogonidae, mostly *Bezzia* sp.) and midge larvae (Chironomidae) represented the only dipterous families that were found in both ponds during the entire sampling period. The number of larvae per square foot in the unfertilized pond gradually increased from 13 to 80, but as the number increased the average weight per insect decreased. The average number of ceratopogonid larvae for the 5-month period was 47 per square foot in the unfertilized pond and 46 in the fertilized pond; the respective weights were 2.75 and 3.55 milligrams. Ceratopogonid larvae also were found at all depths, the greatest concentration occurring in the 18-inch samples.

Stomach Analyses

Samples of bluegills and largemouth black bass were taken from both ponds periodically and the stomachs were removed.

Summaries of the stomach contents of bluegills removed from both pounds in June, July, September and November are given in Tables 3 and 4. Twenty stomachs were examined from fish in the unfertilized pond: 6 in June, 3 in July, 6 in September, and 5 in November.

Thirty-three stomachs were examined from the fertilized pond: 10 in June, 5 in July, 9 in September and 9 in November. In compiling the tables, the food items contained in each stomach were listed according to whether each item was first in relative volume or whether it merely occurred in that stomach.

The bluegills in both ponds gained weight at practically the same rate, although the unfertilized pond was stocked at the rate of 400 bream per acre and the fertilized pond at the rate of 1,500 per acre. In February the average weight per fish was 0.85 gram. In June the average weight per fish was 34 grams, and in November 47 grams. The average standard length in June was 91 millimeters and in November 114 millimeters.

In the unfertilized pond the principal food of bluegills during the entire period was a plant, *Najas*. It has been eaten during every month stomachs were taken; it occurred in 70 per cent of all stomachs examined, and was first in relative volume (40 per cent). Fish (bluegills and top minnows) was the second principal food; occurring in 40 per cent of the stomachs (first in volume in 20 per cent). The next most important foods in order were midge larvae (Chironomidae), dragonfly nymphs (Anisoptera) and water-boatmen (Corixidae). Midge larvae occurred in 30 per cent of all the stomachs examined, and in June these larvae were first in relative volume in 50 per cent of the stomachs. After July, chironomids were found in only one stomach. Dragonfly nymphs were first in volume in 15 per cent of all stomachs and occurred in 20 per cent. Although water-boatmen occurred in 25 per cent of all stomachs examined, they were never first in volume.

Pearse (1918) found that bluegills in Wisconsin lakes during 1914 and 1915 fed mostly on insects (46.2 per cent) and entomostracans (24.9 per cent). He listed as the chief items of food for this fish: Chironomid larvae, amphipods, chironomid pupae, snails, fine debris, *Aphanothece*, copepods and cladocera.

Leonard (1939) in studying the feeding habits of the bluegill in Ford Lake, Michigan, collected 42 fish samples on one day and divided them into three size groups according to average standard length. He stated: "Members of the group of smallest fish (15-26 millimeters) fed almost exclusively on plankton, small mayfly nymphs and chironomids. Plankton, chironomids and aphids bulked about the same in the group of middle-sized fish (33-50 millimeters), but the Odonata were almost as abundant . . . . The largest specimens (105-130 millimeters) fed on anisoptera dragonfly nymphs almost to the exclusion of other groups."

In the stomachs of 100 bluegills taken from Reelfoot Lake, Tennessee, during 1939, McCormick (1940) found 52 per cent by volume of plant material, 34.64 per cent chironomid larvae, and 13.36 per cent other animal forms. Most of the plant material was *Ceratophyllum*. In 1940, another food study of fish in Reelfoot Lake was made by Rice (1941). In 18 bluegills (average length 130 millimeters) he found 40

per cent by volume of the stomach contents was plant material, 22.22 per cent miscellaneous Diptera, 13.44 per cent stoneflies and 25.34 per cent miscellaneous animals. The plant material consisted largely of filamentous algae and duckweeds.

Howell, Swingle and Smith (1941) reported that, for bluegills weighing more than 1 ounce, midge larvae and pupae (Chironomidae) were the most important food in Alabama lakes and ponds. These larvae were first in volume in 35.5 per cent of the stomachs examined and occurred in 71 per cent. Dragonfly nymphs, caddisfly larvae, ceratopogonid larvae and micro-crustacea were the other important foods listed. The conclusion was reached that although bluegills do eat plant foods, animal foods are preferred, especially insects, and that "when large quantities of plant foods are being consumed it indicates that there are too many fish in the pond or lake competing for the same animal foods."

As was pointed out previously, the fish seemed to feed on *Najas* quite consistently in the unfertilized pond, which produced only 147 pounds of fish per acre. In the fertilized pond the fish fed largely on insect larvae, and the pond produced 382 pounds of fish per acre. Table 3 indicates that June was the only month when there were plenty of insects in the unfertilized pond. The weight of bottom organisms in this pond dropped from 39.12 milligrams per square foot in June to 11.17 milligrams in July (Figure 1), thus showing a scarcity of insect foods.

The bluegills in the fertilized pond seemed to have a different preferred food each month. In June, micro-crustacea (cladocera, copepods and ostracods) were the principal food. These zooplankters ranked first in 80 per cent of the stomachs analyzed that month and occurred in 90 per cent. At this time the fish weighed slightly more than 1 ounce and seemed to prefer the plankton forms. After June the micro-crustacea remained a common food but were first in relative volume in but one stomach.

Insects became the principal food of the bream examined in July, although a few insects were eaten in June. The most important insect food was midge larvae. These larvae were first in relative volume in 27.3 per cent of all stomachs examined and occurred in 69.6 per cent of the stomachs. Other important foods were tadpoles, dragonfly nymphs and caddisfly larvae. Tadpoles were first in relative volume in 15.1 per cent of the stomachs and occurred in 21.2 per cent. Dragonfly nymphs were first in volume in 9.0 per cent and occurred in 15.1 per cent. Caddisfly larvae were first in volume in 3.0 per cent and occurred in 18.1 per cent.

Phantom midges (Chaoborinae) were not eaten by a single bluegill examined, although these larvae were the most numerous organism in the pond from September until the time the pond was drained. It seems that bluegills do not prefer phantom midges as a food when plenty of chironomid larvae are also present. In other fertilized

ponds,[2] white crappies (*Potomoxis annularis* Raf.) weighing 0.5 to 3.0 ounces ate *Chaoburus* larvae as their principal food during August and September, 1938 and 1939. These ponds were also stocked with bream, but the bream during the same months preferred chironomid and ceratopogonid larvae.

The data from largemouth black bass stomachs have not been presented in tabular form, for only three or four individuals were removed from each pond during the whole period. Practically the only food eaten after June consisted of bluegills. The largemouth black bass evidently became large enough to begin eating fish between June 24 and July 26, for the stomachs taken from fish captured on the latter date contained fish for the first time. The individual fish then weighed approximately 1½ ounces.

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THE SPAWNING MIGRATION OF RAINBOW TROUT AT SKANEATELES LAKE, NEW YORK

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ABSTRACT

At Skaneateles Lake, New York, the main body of migrating rainbow trout entered Grout Brook, a tributary stream, in April, 1941, at high water when the maximum temperature entered an observed range of 42° to 55° F. The attendant increased flow of water which resulted from rain and melting snow might have affected the migration. Thunderstorms seemed to have a depressing effect upon the numbers of fish entering the counting trap. The migration was of uniform intensity during any period of the day or night.

INTRODUCTION

Rainbow trout (*Salmo gairdnerii*) occur in all of the Finger Lakes of central New York and the species has been the focal point of much interest in the region because of the conspicuous nature of the spawning migration and because such large fish are caught by anglers when the trout are in the streams in the spring. A study of the fishery was undertaken at Skaneateles Lake, one of the Finger Lakes, and a weir was constructed on Grout Brook, the only tributary stream known to be used by rainbow trout for spawning. Skaneateles Lake was chosen for the study because the nature of the watershed assured control over the trout, since the spawning tributary was not large and the lake was one of the smallest in the region. Some of the information concerning the spawning migration of the rainbow trout of the lake form the basis of this paper.

THE TIME OF MIGRATION

The upstream migration of the greater part of the adult population of rainbow trout seems to be correlated definitely with the temperature and flooding of the stream in which the migrants are found, and has been observed to extend over a period from February to the latter part of May. The reasons for very early upstream movement of a small number of migrants are not known, but it is possible that midwinter thaws play a part. Early migrating fish have been observed under the ice in the stream in February by game protectors, who also report finding poachers in possession of rainbow trout during the same month. The author has seined the trout from the stream in February, and all fish caught except one have been males. A ripe female was also reported to have been taken from the stream in February by a poacher. Green females have been captured in the lake at the mouth of Grout Brook as late as May 16, and in the stream on May 20.

On April 5, the opening day of the 1941 trout season, when the lake was frozen over, 30 fish were reported by game protectors to have been taken from Grout Brook by anglers. Only one female was observed and she was spent and possibly returning to the lake, indicating that some females may participate in the early runs, deposit their eggs, and yet return to the lake before the principal run of fish occurs. Late migrants may be governed by the degree of maturity of the sex products.

The majority of the rainbow trout usually migrate in April, at high water, when the maximum temperature enters an observed range of 42° to 55° F. (5.5° to 12.8° C.) During the period when the trap was operated on Grout Brook in 1941, 243 rainbow trout were captured and tagged (Fig. 1).

Males never have been taken on their way back to the lake until the end of May but, on the other hand, females may be taken as kelts or spent fish on their way back to the lake as early as 5 days from the date of entering the trap on their way upstream. Eight females, comprising all of the fish taken as kelts at the weir in 1941 before operations ceased, were in the stream for an average of 9 days. Two females taken from the spawning bed in which they were depositing eggs had been in the stream for 8 and 10 days, respectively, indicative of the time require for the two fish to mature the sex elements and to begin spawning.

Reasons for the Migration

In 1941, before the ice on the lake broke up, 106 fish were taken at the weir in 10 days, coincident with an increased flow of water as a result of melting snow. Wind action could not have operated while the lake was frozen over although it has been shown to have some influence in governing the migration of rainbow trout at Paul Lake, British Columbia (Mottley, 1938). At Skaneateles Lake, wind must be ruled out as a factor influencing the migration, in 1941 at least, because the trout migrated upstream in spite of the ice cover (Figure 1). The first group of fish came into the trap when the stream water was clear and when the temperature of the water had reached a maximum of 41° F. in the late afternoon of April 2. On April 4 the stream became roiled and the water did not clear until April 16. The apparent activating agent which started the run of fish in 1941 seems to be temperature. The attendant increased flow of roiled water, by passing into the lake and melting the ice at the mouth of the stream, might have been an aid in orienting the trout as to the location of the creek.

The time of day or night had no apparent effect upon the numbers of fish entering the trap at various periods (Table 1). The first eight fish to enter the trap are not included in the table because the time of arrival was not recorded. The difference in the number of fish entering the trap during the periods and during day and night is

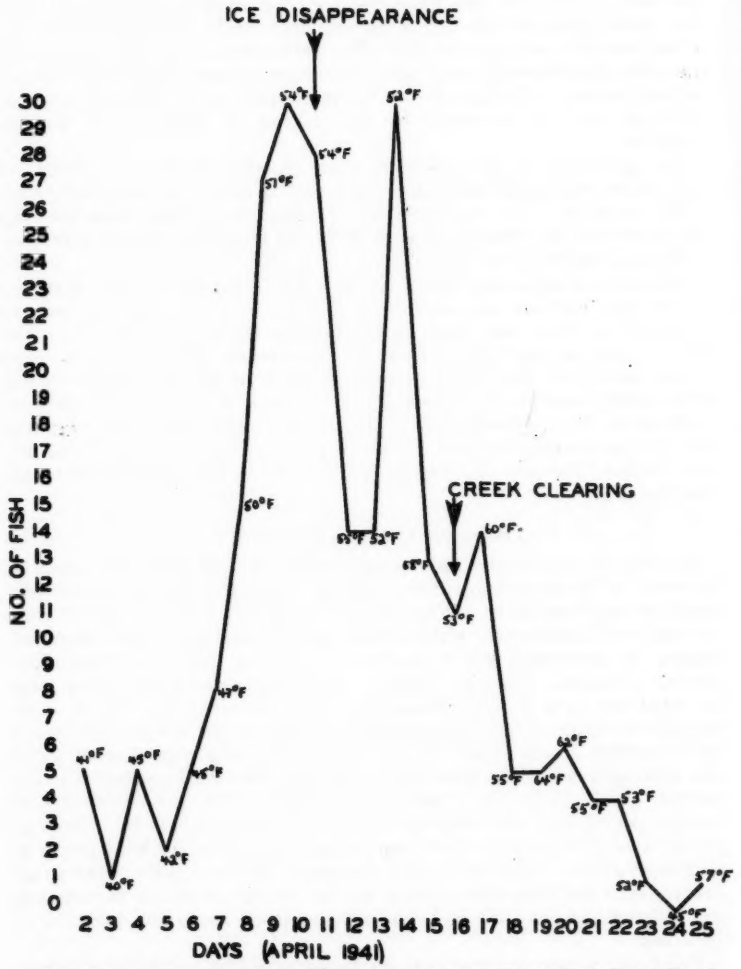

Figure 1.—The numbers of rainbow trout entering the trap at Grout Brook in April, 1941

not significant (chi-square value for the periods = 0.34) when the periods are made comparable by converting the numbers of fish per period into the numbers of fish per period-hour. There continued to be no difference in day and night and period-hour migration after the stream became clear on April 16 (Figure 1), indicating that the disappearance of the roily condition of the water did not prevent fish from migrating during the day.

Table 1.—Number of rainbow trout entering the trap at various periods during 22 days in April, 1941. (Total number, 235)

Periods	Number of fish	Fish per period-hour
1:00 a.m. to 8:00 a.m.	73	10.4
8:00 a.m. to 1:00 p.m.	51	10.2
1:00 p.m. to 6:00 p.m.	53	10.6
6:00 p.m. to 1:00 a.m.	58	8.3

Mottley (1938) stated that thunderstorms produced noticeable effects on the intensity of migration of rainbow trout at Paul Lake, British Columbia, in 1935-36, and that the warm, bright weather which seemed to favor a high intensity of migration also appears to build up the conditions necessary for electrical storms. Under such conditions a sudden reduction in the number of fish taken in his trap was very noticeable. His observations appear to be corroborated by the effect of thunderstorms upon the migration of trout at Grout Brook on April 12-13, 1941. The coincident decline of the numbers of fish entering the trap was quite marked (Figure 1).

It appears that at Skaneateles Lake, those fish which reach the south end of the lake at the inlet are readily able to move into Grout Brook, the spawning tributary, and that they are moving in all directions around the mouth of the stream as evidence of such movement is seen in the various directions in which the fish are heading when taken in gill nets set off the mouth of the stream. Some of the fish are near the inlet prior to migration, as indicated by the number of adult fish which may be taken in gill nets set off the mouth of the stream as much as 2 weeks before adult trout are taken at the weir during the principal migration.

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FISH POPULATIONS OF FIVE FLORIDA LAKES

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Abstract

Population studies were made of five representative lakes in the Ocala National Forest, Florida, which ranged from immature to very mature in ecological age and development. The largemouth black bass made up a constant proportion of the total weight of the fish population. There was a direct relation between the number of pounds of fish per acre and the degree of ecological maturity of the lake. The number of largemouth black bass was from 12 to 27 per acre, which was less than one-third of the number stocked 3 years previously.

The make-up of the supporting populations of other species of fish was variable from lake to lake, indicating that there may be considerable variation in species associations. The total number of legal fish per acre also varied from lake to lake but the weight was greater in the more mature lakes. The total weight of supporting populations was also related to the maturity of the lake. The ratio of supporting populations to predators was constant. Thirty-one per cent of largemouth black bass of legal size taken weighed 3 pounds or over.

Largemouth black bass fingerlings of the year were taken in two lakes and suckers of the year only in one. No immature garfish were taken, a possible indication that adequately stocked lakes are susceptible to biological control of predatory fishes, except under certain circumstances.

Introduction

Studies of fish populations in the lakes of the Ocala National Forest have been made as a part of an investigation for the development of a management program. The purpose of the studies was to determine the ability of these bodies of water to support game fish, aside from the information they provide concerning the ecology of Florida lakes which is essential for increasing the yield of desirable species. The studies also may serve as a basis for additional investigations involving stocking policies and will assist in the study of lake fertility.

The bodies of water in the region of the present investigation are solution lakes formed by dissolution of the limestone substratum from beneath the upper layer of sand. They have neither inlets nor outlets. On the whole they are shallow, attaining a maximum depth of about 25 feet. The exception is the sinkhole type which is very deep and is usually connected with underground waters through openings in the substratum. These are less common and we are not concerned with them here.

The lakes studied are tropical lakes of the third order, according to

the classification proposed by Whipple (1927). Although some of them are small, the characteristics of size, depth, or occupancy by aquatic vegetation employed to distinguish ponds from lakes do not hold.[1] For example there is a 3,000-acre lake in the forest which is no deeper than some of the bodies of water 3 to 5 acres in size. At the same time many of these smaller bodies of water contain little or no aquatic vegetation.

The lakes considered in this study have been classified according to ecological development on the basis of Shelford's (1911b) classification of ponds since it was found to fit more nearly than any other. Those that are younger have a high oxygen content, bare or sandy bottom, little marginal vegetation, and the least plankton. As they pass through progressive stages of maturity, there is an increase in the accumulation of humus and accompanying occupancy by aquatic vegetation, until stages of development are attained which are characterized by an abundance of humus and increasingly large areas of emergent and submerged aquatic plants. Lakes approaching senescence have deep deposits of humus yielding obnoxious gases and the surface is more or less entirely covered with floating aquatics such as *Nymphaea.*

According to Shelford (1911a) the younger bodies of water should support pickerel, red horse, small minnows, and perch. With the accumulation of humus, pickerel and red horse disappear and black bass, bluegills, pumpkinseed sunfish, and white crappies make their appearance. Finally the chub sucker, warmouth bass, spotted catfish, mud minnow and dogfish are found in the older lakes.

Lakes in various stages of ecological development in Florida have populations more or less uniform in composition. The difference is in the number and weight of fish supported rather than the species. All of the lakes contained the chub sucker, *Erimyzon sucetta;* brook silversides, *Labidesthes sicculus;* mosquito fish, *Gambusia holbrookii;* at least two species of *Fundulus;* two species of sunfish, *Eupomotis microlophus* and *Helioperca macrochira*; the largemouth black bass, *Huro salmoides;* and the warmouth bass, *Chaenobryttus gulosus. Heterandria formosa* and *Hololepis barratti* also occurred, but in insignificant numbers. Some of the lakes had the Florida spotted or shortnose gar, *Lepisosteus platyrhincus.*

Description of the Lakes

Clearwater Lake is the largest of the lakes studied and is also the youngest ecologically, has an area of about 24 acres and supports no aquatic vegetation except for an occasional invasion by grass. The bottom has some accumulation of humus both along the shore and in

[1]Welch (1935) used the term pond "for that class of very small, very shallow bodies of standing water in which quiet water and extensive occupancy by higher aquatic plants are common characteristics."

the deeper parts. It slopes gradually and the depth ranges up to about 12 feet.

Buck Pond has an area of 18 acres, the bottom is sandy with a shelf about 15 to 25 feet wide around the lake outside of which the bottom slopes off very rapidly to a maximum depth of 25 feet. On the outer edge of this shelf, in about 7 feet of water, is a thick mat of grass which forms a protection for the shore against wave action and affords protection for smaller fishes. An accumulation of humus is found in the deeper parts of the lake and outside the mat of grass. Between the grass and the shore may be found occasional growths of submerged aquatic plants and a few reeds.

Big Prairie Pond is almost 4 acres in area and has a fairly thick accumulation of muck. Its maximum depth is about 6½ feet. In the center of the lake is a small amount of floating spatterdock, *Nymphaea* sp. There is some submerged aquatic vegetation, but *Utricularia* and other submerged types are kept under control by the feeding activities of the chub or lake sucker, *Erimyzon sucetta*.

First Pond is about 7 acres in area and up to 9 or 10 feet in depth, has a great deal humus accumulated on the bottom and a more extensive area covered with floating *Nymphaea*.

Little Steep Pond is 2.1 acres in area and entirely covered with surface vegetation interspersed with some submerged aquatics. The bottom has a very thick mat of humus which is filled with gases caused by anaerobic decomposition. In all probability this lake has passed its climax and has reached a stage of senescence, and was considered the most mature of those studied.

In all of these lakes the pH of the water is 5.4 to 5.6 throughout the year. They have shallow basins and average depths ranging from 3 to 13 feet. This shallow depth is characteristic of Florida lakes regardless of size. None of the lakes in Ocala National Forest is deeper than 27 feet except a few of the sinkholes which were not included in this study.

Methods

To make accurate counts of the populations the fish were killed with powdered derris. All other methods of study are selective of certain species and have other disadvantages that impair their accuracy. Eschmeyer (1937, 1938) used derris to remove stunted populations of perch from certain Michigan lakes. Leonard (1939) studied the effect of various concentrations of rotenone on different species of fish and determined the lethal dose. Thompson and Bennett (1939a, 1939b) used derris to study the composition of fish populations in certain Illinois lakes. Inasmuch as derris kills the entire population there is no question as to its effectiveness.

Plane-table maps had been made of all these lakes on an earlier survey. Since all solution lakes maintain the same level as the water table in the vicinity there may be a fluctuation of 2 or 3 feet in a short

period of time depending upon the season. Shortly before the study was made they were sounded thoroughly so that the volume of water could be calculated accurately.

The derris powder, containing 5 per cent rotenone, was first mixed in tubs. Enough water was added to give it a doughy consistency and after the lumps had been worked out, additional water was added so that the mixture would go through the sprayer hose. On the first two lakes it was spread by hand directly from the tubs as the boat was being paddled about. Later an orchard sprayer was installed in a 50-gallon steel drum for this purpose.

First the vegetation areas along the shore, where the chemical would not penetrate, were sprayed carefully. The nozzle was then removed and the remainder of the lake was treated. As the derris was pumped out, the end of the hose was allowed to drag in the water in front of the motor and near the propeller. This caused a very rapid and thorough mixing of the water.

According to Leonard (1939) 0.5 p.p.m. of derris is as effective as larger amounts. Various proportions were tried in the Ocala Forest lakes. In the first three, the volume of water was small and the amount of derris used was equivalent to 1.0 p.p.m. In the two larger lakes it was found that 0.5 p.p.m. was effective, although 0.84 p.p.m. was used in one lake to be sure that more than sufficient was added to kill all of the fish. The effect was almost immediate and by the end of the day a large percentage of the fish had been collected.

Effect of Derris Treatment

No tests, other than general observations, have been made to determine the effect of rotenonè on the fauna. *Chaoborus* larvae were killed by all amounts used, and these animals were observed drifting toward shore as a result of wind action. Aquatic earthworms (*Sparganophilus*?), leeches, and the salamander (*Pseudobranchus striatus*) were all killed by the drug.

The very strange and gratifying feature of the results is that the soft-shell turtle (*Amyda ferox*), which is one of the predators, was also affected. It was found that late the first day of the treatment, turtles came to the shore as if gorged with food and seemed unable to crawl and on the second day they were dying. The turtles were collected and weighed together with the fish. In the last lake studied (Buck Pond) 0.5 p.p.m. of derris was found to be a borderline treatment and the turtles were affected only enough so that a part of them could be collected. The importance of the soft-shell turtle can be estimated from the data presented.

In attempting to explain the exact effect of derris on the turtles one must rely on conjecture. Probably they "breath" during a considerable portion of the time through the cloacal organs, since they have a habit of burying themselves in the bottom and lying dormant for long

periods. In Buck Pond many turtles were seen in a semi-sluggish condition after the derris was applied, but they could not be captured since they were still too active. The ratio of fish to turtles in this lake was higher as a result and undoubtedly indicated that all were not taken.

Lake Populations

Probably the most important aspect of the population studies is the total weight of fishes produced per acre. This is a concrete basis for measuring and comparing the fertility of one body of water with others. Secondly, the make-up of populations gives us an important clue as to possible methods for producing additional numbers of desirable species. Finally, the number of legal fish per acre may be a guide as to the amount of fishing a body of water will support and the amount of stocking necessary to keep up the game fish to maximum or even for increasing production.

Little Steep Pond supported a population weighing 105.25 pounds per acre (Table 1). Of the 8½ pounds of fish of legal size 6 pounds were largemouth black bass. There was an unusually large number of sunfish of all sizes as well as large numbers of minnows. This lake had the largest number of legal size largemouth bass per acre, but the weight was not as great as it should have been in proportion to their relative abundance. The garfish averaged 5 fish per acre. The soft-shell turtles weighed 16 pounds per acre.

Table 1.—Fish populations (per acre) of Little Steep Pond

Species	All sizes		Percentage of total weight	Legal sized	
	Number	Weight (pounds)		Number	Weight (pounds)
Largemouth black bass....	26	12.99	12.34	5.2	6.1
Sunfish	4,210	48.10	56.26	4.7	1.2
Warmouth bass.....	845	11.11		2.8	1.1
Chub suckers.....	25	23.54		....	....
Minnows	3,660	1.64	31.40	....	....
Shortnose gar.....	5	7.87		....	....
Total	....	105.25	100.00	12.7	8.4
Soft-shell turtles.....	7	16.31	....	....	....

Only 5 sunfish and 3 warmouth bass were of legal size which is surprising because 48 adults per acre had been stocked 3 years previously. It is also interesting to note that 29 fingerling largemouth bass per acre had been stocked in 1938 and only 26 bass were removed in these studies.

First Pond supported 110 pounds of fish per acre (Table 2). On the other hand, the 2.5 largemouth bass of legal size taken per acre weighed 10 pounds (compared with Little Steep Pond, Table 1). There were 62 sunfish and 2 warmouth bass of legal size, yielding a total of

Table 2.—Fish populations (per acre) of First Pond

Species	All sizes		Percentage of total weight	Legal sized	
	Number	Weight (pounds)		Number	Weight (pounds)
Largemouth black bass....	27	16.08	14.60	2.5	10.2
Sunfish	88	20.99	20.00	62.3	13.6
Warmouth bass.....	17	1.09		1.5	0.3
Chub suckers.....	159	71.90	65.40	....	....
Minnows	258	0.30		....	....
Shortnose gar.....	none	....			
Total	....	110.36	100.00	66.3	24.1
Soft-shell turtles.....	6	17.26	....	....	....

24 pounds per acre; about three times that taken in the Little Steep Pond.

The chub suckers in First Pond numbered 159 per acre and weighed 72 pounds or about three times the weight in Little Steep Pond. The total number of sunfish and minnows was much smaller, so that the chub suckers made up the bulk of the supporting populations, whereas sunfish had played this role in Little Steep Pond. No garfish were taken.

In 1938, First Pond was stocked with 36 largemouth black bass fingerlings per acre and in 1939 with 75 per acre. It yielded a total of 27 per acre; in contrast to Little Steep 13 adult sunfish were stocked per acre in 1938 and 62 were removed.

Big Prairie Lake had very little floating and practically no submerged vegetation. It supported 61 pounds of fish per acre (Table 3) of which 2 were legal-sized largemouth bass weighing 3 pounds. There were 28 sunfish and 3 warmouth bass yielding a total of 13 pounds of legal fish. The shortnose gar averaged 2 per acre.

Sunfish of all sizes were more numerous, minnows almost absent and the chub sucker less numerous than in First Pond. At the same time suckers made up the larger weight of supporting populations. There was a smaller weight of soft shell turtles in this lake, namely, 8 pounds

Table 3.—Fish populations (per acre) of Big Prairie Lake

Species	All sizes		Percentage of total weight	Legal sized	
	Number	Weight (pounds)		Number	Weight (pounds)
Largemouth black bass....	12	6.63	10.9	1.6	2.9
Sunfish	375	12.58	22.6	27.5	9.3
Warmouth bass.....	5	1.14		2.6	0.9
Minnows	negligible		66.5	....	....
Chub suckers.....	47	38.42		....	....
Shortnose gar.....	2	2.05		....	....
Total	....	60.82	100.00	31.7	13.1
Soft-shell turtles.....	3	7.80	....	....	....

per acre as contrasted with 16 and 17 pounds, respectively, in Big Steep Pond and First Pond.

There is some basis for believing that the shortnose gars replace some of the legal fish. If the weight of shortnose gars is added to that of the legal fish it puts the three lakes on a more equitable basis (Tables 1-3). There would be 16, 24, and 15 pounds of legal fish per acre. However, until more information has been acquired no definite conclusion can be stated. Only two of the lakes studied had shortnose gar in the population.

All of the lakes discussed so far had quite an accumulation of humus on the bottom and considerable amounts of vegetation. The next two were quite immature with almost no humus and little or no vegetation of any kind.

Buck Pond supported only 33 pounds of fish per acre (Table 4). There were 2 legal largemouth bass and 13 legal sunfish. A total weight of 7 pounds of legal fish was taken, or about one-half that of Big Prairie Lake. The amount of chub suckers in this lake was small, but the weight of all sunfish was about the same as that for Big Prairie Lake. No shortnose gar were present. Whereas the weight of soft-shell turtles had dropped from about 17 pounds to 8 pounds in other lakes, it now was reduced to about 2 pounds.

Table 4.—Fish populations (per acre) of Buck Pond

Species	All sizes		Percentage of total weight	Legal sized	
	Number	Weight (pounds)		Number	Weight (pounds)
Largemouth black bass....	19	7.60	23.2	2.2	4.5
Sunfish	233	13.80	48.8	12.7	2.3
Warmouth bass.....	83	2.18		0.8	0.1
Chub suckers.....	57	9.10		....	....
Minnows	34	0.06	28.0	....	....
Shortnose gar.....	none	....		....	....
Total	....	32.74			
Soft-shell turtles.....	1	2.28	100.0	15 7	6.9

Clearwater Lake had no vegetation of any type except where the shore grasses had invaded in a few places. This lake (Table 5) supported only 22 pounds of fish per acre, and although it yielded about as many largemouth bass as any lake in the group there was only 0.2 legal largemouth bass per acre weighing 0.03 pounds. Only 18 legal sunfish were taken and no warmouth bass. The soft-shell turtle weighed about 4 pounds per acre. Chub suckers had dropped to 7 per acre weighing 6.5 pounds, although the sunfish weighed approximately 13 pounds which is about the same as that collected from Buck Pond and Big Prairie Lake.

The population of these lakes should be divided on the basis of predator and supporting populations, and the supporting populations

Table 5.—Fish populations (per acre) of Clearwater Lake

Species	All sizes		Percentage of total weight	Legal sized	
	Number	Weight (pounds)		Number	Weight (pounds)
Largemouth black bass....	19	2.96	13.3	0.2	0.03
Sunfish	108	12.57	57.3	17.8	4.80
Warmouth bass.....	1	0.18		none	....
Chub suckers.....	7	6.37	29.4	....	....
Minnows	84	0.14		....	....
Shortnose gar.....	none	....		....	....
Total	....	22.22	100.0	18.0	4.83
Soft-shell turtles.....	2	3.80	....	....	....

should be subdivided into panfish and rough fish. The predator populations should include garfish and largemouth black bass. All others should be considered as supporting populations. The panfish include sunfish and warmouth bass, while the rough fish include minnows and chub suckers.

In all of the lakes the number of largemouth black bass of all sizes was very much the same. It ranged between 19 and 27 except in Big Prairie Lake, where 12 per acre were taken (Table 6). In contrast, the total weight of largemouth bass per acre was progressively less in the less mature lakes. This is especially striking if the weight of shortnose gar is added in so that all predator fish are considered. Thus the weights would be 20.86, 16.08, 8.68, 7.6 and 2.96 pounds per acre arranged according to the maturity of the lake. At the same time they constitute a fairly constant percentage of the weight of the total populations.

The total weight of fish, in the same way, may be arranged, according to the maturity of the lake (column 5 of Table 6). On the other hand, the make-up of the supporting populations shows another trend. In the first place the minnows do not at any time constitute an important portion of the total (Tables 1 to 5). The importance of their contribution to the food chain is unknown, but in only one lake do they reach even 1 pound per acre.

Sunfish and chub suckers seem to be the principal link in the food chain and to be the bulk of the supporting population. In three lakes the sunfish constituted 50 per cent or more of the supporting popula-

Table 6.—Standing populations per acre of each lake

Lake	Number of largemouth bass	Weight of largemouth bass (pounds)	Weight of predators (pounds)	Weight of all fish (pounds)
Little Steep.....	26	12.99	20.86	105.25
First Pond.....	27	16.08	16.08	110.32
Big Prairie.....	12	6.63	8.68	60.82
Buck Pond.....	19	7.60	7.60	32.74
Clearwater	19	2.96	2.96	22.22

tion while in the other two chub suckers constitute 65 per cent or more. These data indicate that the association within a lake may be formed in a variety of ways.

In the same way that the fish populations are smaller in lakes which are less mature, the population of soft-shell turtles decreases with the reduced fish population. In Little Steep Pond and Big Prairie Lake turtles weighed 16 and 17 pounds per acre, respectively. In the younger lakes they were reduced to 2 and 4 pounds per acre.

Most important, from an experimental standpoint, is the relationship of the various fish populations to one another (Table 7). Little Steep Pond is the exception in the table because of the possibility that it is approaching senescence and has exceeded the point of maximum production.

In Column 2 (Table 7) are shown the weights of supporting populations which include all fish that might be used for food by either largemouth black bass or shortnose gars or turtles. In Column 3 appears the weight of all predators which include shortnose gar, largemouth black bass, and soft-shell turtles. Both of these population divisions follow the maturity of the lakes rather closely.

Table 7.—Relationship between supporting and predator populations

Lake	Weight of supporting populations (points)	Weight of all predators (points(	Ratio
Little Steep	84.39	37.17	2.27:1
First Pond	94.23	33.34	2.83:1
Big Prairie	58.14	16.48	3.16:1
Buck Pond	25.14	9.88	2.54:1
Clearwater	19.26	6.76	2.28:1

When a ratio is calculated between the supporting and predator populations, it is quite constant from lake to lake. This ratio shows that between 2 and 3 pounds of fish per acre are necessary to support 1 pound per acre of predators, whatever they might be. If this ratio holds after additional lakes have been studied, it will have considerable effect upon management and stocking policies.

If some of the predators, soft shell turtles or shortnose gars, could be eliminated we might assume that there should be a commensurate increase in the weight of largemouth bass. This assumption is illustrated in Table 6, where the weight of garfish was added to the weight of largemouth bass, resulting in a total weight which was judged to be associated with the maturity of the lakes.

We have reason to believe that where lakes are adequately stocked with largemouth bass the predation of gars is not a problem. This is borne out by observations where we have conducted gar control studies in the Forest and will undoubtedly be proven as more population studies are completed. Lakes in which adult gar control has been

practiced along with adequate stocking show no evidence of the return of these predators. In the two lakes where gars were taken none smaller than 16½ inches was removed. The young, no doubt, fell prey to the largemouth bass.

The story of these population studies would not be complete unless something were said of the number and size of the larger largemouth bass taken and unless mention were made of the peculiarities of the populations. From a total of 77 legal largemouth bass collected, 24, or approximately 31 per cent, weighed 3 pounds or over. The legal length in Florida is 12 inches. Two largemouth bass, 24 inches and 24½ inches in length, weighed 9½ pounds and 9 pounds and 11 ounces, respectively. In the two most immature lakes, fingerlings of the year were taken, but none in the others. All studies were made shortly after the spawning season.

Although there was a large population of chub suckers in all of the lakes, fingerlings of the year were taken in only one lake, Buck Pond. In the others they ranged from 5½ to 14½ inches in length. In the course of seining operations during the preliminary surveys of these lakes, it was found that sucker fry and fingerlings disappeared from the habitat very soon after the spawning season.

Conclusions

Largemouth black bass constitute a fairly constant proportion of the populations of the lakes studied (between 11 and 23 per cent) and that proportion is determined somewhat by the presence of other fish predators such as gars. The total number of largemouth bass and the number of legal largemouth bass is dependent upon the ecological maturity of the lake. More mature bodies of water support a greater weight per acre.

Lakes of different degrees of maturity support fish populations in proportion to that maturity. The more mature the lake the greater the population. The exception is Little Steep Pond which has passed the maximum and probably is approaching senescence. Other studies will be necessary to arrive at a definite conclusion.

The supporting populations for predators varies in composition and may therefore be made up in a variety of combinations, allowing a wide latitude in experimental work for increasing the weight of game fish per acre. Soft-shell turtles and other predators were found in proportion to the maturity of the lake as in the case of the other fishes.

The ratio of all predators, including largemouth black bass, to the supporting populations, lies between 2.27:1 and 3.16:1, but is probably in the neighborhood of 3:1. It therefore takes approximately 3 pounds of fish to support 1 pound of predators in the associations studied. Approximately 31 per cent of the legal largemouth bass averaged 3 pounds or more.

The number of shortnose gar in the two lakes where they were found was small and no immature specimens were taken. It is possible that

in lakes where stocking is adequate and adult shortnose gar have been controlled they will not be a problem. However, the presence of shortnose gars reduces the number of legal largemouth bass.

A drastic revision of our stocking standards may be necessary since the total number of largemouth black bass taken per acre did not approach the number stocked, by up to one-third. The interesting fact is that the number of largemouth bass per acre was so similar in the various lakes.

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GONAD MEASUREMENTS AND EGG COUNTS OF BROWN TROUT (*SALMO TRUTTA*) FROM THE MADISON RIVER, MONTANA[1]

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ABSTRACT

Gonad studies were made on 41 female and 15 male brown trout, *Salmo trutta*, from the Madison River, Montana. The left ovary, with some exceptions, was found to be longer and heavier and to produce more eggs than the right. The average numbers of eggs produced by the right and left ovaries were 589 and 680, respectively (38 fish), and the average of all eggs per female for fish that were weighed was 1,285 (37 fish). There seemed to be little or no correlation between the length, weight, condition, or age of these females and the number of eggs produced. The gonads comprised 1.7 per cent of the body weights of the males. The weight of the testes did not show any correlation with the length, weight, age, or condition of the fish.

INTRODUCTION

During November and December of 1936, while engaged in a study of the incidence of furunculosis in fishes of the Madison River, Montana, the writers had an opportunity to secure about one hundred brown trout spawners for studies of the gonads. Most of these fish came from the traps of the former U. S. Bureau of Fisheries in the Meadow Lake region, Madison County, but a few were taken from the traps of the Montana State Fish and Game Commission above Hebgen Reservoir, Gallatin County, Montana.

Collections were made at random from the traps soon after the fish had entered. Special effort was made to avoid any selection in order that the sample might be representative of the run. However, only those fish were saved for study, which, after examination, showed the egg sacs to be intact or the testes to be firm. Fish in this stage of maturity are termed "green" in hatchery parlance. Fifteen males and 41 females were retained for study.

The standard and total lengths of each fish were measured to the nearest ⅛ inch and the weight was recorded to the nearest 2 ounces. Actual counts were made of all eggs. Egg measurements were made with a vernier caliper to the nearest 0.1 millimeter. Our figures represent an average of 15 eggs taken at random from both ovaries. Gonad weights were taken by means of a torsion balance to the nearest 0.1 gram. All measurements were made while the fish were in a fresh condition, usually within 2 or 3 hours after the fish were captured.

[1]Contribution from the Michigan Institute for Fisheries Research and the Zoology Department, Montana State College.

The age of each fish was determined by the usual method of counting the annuli on the scales and the condition factor (K) was calculated from the formula adopted by the Fisheries Board for Scotland (Nall, 1930).

Measurements of Ovaries

A comparison was made between the right and left ovaries of eight individuals as to their length, weight and number of eggs. As shown in Table 1, the left ovary is generally longer and heavier than the

Table 1.—Comparison between the length, weight, and number of eggs for the right and left ovaries

[Averages are given in the bottom row]

Standard length of fish (inches)	Weight of fish (ounces)	Right ovary			Left ovary		
		Length (millimeters)	Weight (grams)	Number of eggs	Length (millimeters)	Weight (grams)	Number of eggs
12.25	16	128	29.7	443	153	36.2	550
13.25	18	133	42.3	580	174	47.4	658
13.75	22	156	44.9	600	187	43.9	574
14.25	24	148	44.9	567	175	56.7	721
14.50	24	125	28.7	400	188	61.7	856
15.00	24	151	27.6	368	179	35.0	503
15.12	20	94	17.3	228	150	31.5	431
15.50	24	132	23.7	297	150	28.5	370
14.20	22	133	32.4	435	169.5	42.6	583

right. It also usually contains more eggs. This difference is due primarily to the anatomical arrangement of the organs in the coelomic cavity. In the brown trout, the posterior portion of the intestine usually bends strongly to the right, thus crowding the right ovary at its caudal end. The length of the ovary is inversely proportional to the degree of crowding. However, the left ovary is not always the longer. One fish was observed to have a longer right ovary and it was interesting to note that this specimen had an intestine which bent to the left instead of the right. In one or two fish the ovaries were of approximately equal length, with the intestine bending neither to the right nor the left.

The average numbers of eggs in the right and left ovaries from 38 females were 589 and 680, respectively, showing that the shorter ovary as a rule contained fewer eggs.

Gonad weights and egg counts were made for four females collected above Hebgen Reservoir, approximately 1 month before spawning began, and these data were compared with those for five other fish taken at the same place during the spawning season. Table 2 shows that the ovaries of the brown trout collected before the spawning season averaged 3.4 grams as compared to 73.5 grams for those collected during spawning.

Table 2.—Comparison of the weights of the ovaries and of the numbers of eggs for brown trout collected above Hebgen Reservoir one month before spawning began and during the spawning season

[Averages are given in the bottom row of both the upper and lower portion of the table]

Age (number) of annuli)	Standard length (inches)	Weight of fish (ounces)	Weight of ovaries (grams)	Total number of eggs	Number of old eggs
Females taken one month before spawning began—October 9, 1936					
3	14.50	16	4.4	862	3
4	15.00	20	2.7	2,070	1
4	15.00	24	3.2	1,776	2
4	16.00	24	3.6	1,425	28
3.8	15.12	21	3.5	1,533	8.5
Females taken during spawning period—November 18, 1936					
4	14.25	24	101.6	1,288	0
4	15.00	24	62.9	871	4
4	15.12	20	48.8	659	6
4	15.50	24	52.2	667	1
5	15.50	28	102.0	1,073	10
4.2	15.07	24	73.5	912	4.2

If this sample is representative, the weight of the ovaries increases about 20 times during the month prior to spawning. The number of eggs in those females taken early averaged 1,533 as compared to 912 for those taken during the spawning run, while the weights of the females in the latter group averaged 3 ounces greater than the weights of those taken earlier.

Day (1887) reported that early-spawning trout have smaller eggs than those from the latter part of the run and that the size of eggs increases with age and probably with condition of the parent. Our collections did not include specimens from the early and late run and therefore throw no light on this point.

Egg Counts

Actual numbers of eggs for each of 37 females are given in Table 3 (we omitted 4 fish for which we had no weights). The average number of eggs produced was 1,285 for these fish which had an average total length of 15.3 inches and an average weight of 21.4 ounces. This value is very near the number reported by Vladykov and Legendre (1940) for a native brook trout of comparable size. The largest number of eggs was from a fish with a total length of 16½ inches and a weight of 26 ounces, and the smallest number from a 17¼-inch fish which weighed 20 ounces.

Hayford and Embody (1930), in selection experiments with hatchery brook trout, found that selected females produced an average of 1,164 eggs per female their first spawning year as compared to an average of 272 for like females of the general hatchery stock. At the second spawning the selected fish produced an average of 1,916 eggs (fish 16 to 16½ inches, total length). They discovered much variation, however, within the group studied. Some of the larger females produced the smaller numbers of eggs. Nevertheless, they concluded

that, in general, the fast-growing, larger females produce the most eggs.

In our sample there was no marked correlation between the size and weight of the fish and the number of eggs produced. As shown in Table 3, the fish with the greatest length produced 667 eggs, only about one half of the average; on the other hand a specimen almost as large had the highest egg count. Several of the smaller females had counts above the average. Fish with a standard length between 12 and 13 inches averaged 1,364 eggs; between 13 and 14 inches, 1,300 eggs; between 14 and 15 inches, 1,300 eggs; and between 15 and 16 inches, 1,131 eggs.

The conditon of the fish seems to have no relationship to egg production. At least, our sample shows no correlation between condition and the number of eggs. The specimen with the highest K value, however, did produce the largest number of eggs.

According to Nall (1930), female sea trout produce 700 to 800 eggs

Table 3.—Size, age, condition, and number of eggs for 37 Madison River brown trout

[Averages are given in the bottom row]

Standard length (inches)	Total length (inches)	Weight of fish (ounces)	K	Age (number of annuli)	Weight of ovaries (grams)	Number of eggs	Number of old eggs
12.25	13.75	16	0.901	3	65.9	993	0
12.25	14.00	14	0.747	3	73.2	1,045	2
12.50	13.75	18	1.014	3	87.0	1,884	3
12.75	14.37	18	0.888	3	89.4	1,532	1
13.25	14.62	18	0.843	2	89.7	1,238	1
13.25	14.75	22	1.003	3	113.6	1,435	8
13.25	14.87	18	0.801	3	92.9	1,310	6
13.25	14.87	20	0.890	4	98.2	1,410	0
13.25	15.00	16	0.694	3	77.0	1,077	0
13.25	15.00	20	0.867	3	89.2	994	1
13.37	14.87	20	0.890	3	105.5	1,299	8
13.50	14.87	18	0.801	3	93.1	1,454	0
13.75	15.25	20	0.825	3	79.9	1,503	3
13.75	15.25	22	0.908	4	88.8	1,174	0
13.75	15.50	20	0.786	3	94.1	1,328	2
13.75	15.50	20	0.786	3	85.2	1,374	0
14.00	15.62	22	0.845	3	117.1	1,688	0
14.00	15.75	20	0.749	3	108.2	1,794	1
14.00	16.00	20	0.715	5	76.8	1,196	0
14.12	16.00	20	0.715	3	78.7	1,337	1
14.25	15.50	24	0.944	4	101.6	1,288	0
14.25	16.00	20	0.715	3	69.1	1,166	51
14.25	16.12	22	0.769	4	90.2	1,174	0
14.50	16.12	24	0.839	4	100.0	1,377	0
14.50	16.12	24	0.839	4	80.9	839	0
14.50	16.25	24	0.819	4	90.4	1,256	0
14.50	16.25	24	0.819	5	124.3	1,744	0
14.50	16.50	22	0.717	4	97.4	1,067	8
14.75	16.50	28	0.912	4	106.0	2,352	0
14.75	16.62	24	0.765	4	80.2	865	3
15.00	17.00	24	0.715	4	62.6	871	4
15.00	17.00	26	0.796	3	106.1	1,682	0
15.12	17.25	20	0.570	4	48.8	659	6
15.25	17.25	24	0.685	5	95.6	1,104	0
15.50	17.25	26	0.682	4	141.2	1,299	71
15.50	17.25	28	0.799	5	102.0	1,073	10
15.50	17.50	24	0.700	4	52.2	667	0
14.02	15.73	21.4	0.784	3.6	90.5	1,285	5.1

per pound of fish, but he recognized a great deal of variation from this figure. He observed that the smaller fish have more eggs per pound of fish but that the eggs are smaller.

Dahl (1917) reported that the weight of the roe per pound of fish is less in young than in old females but that the number of eggs decreases as the age and weight of females increase, *i.e.*, young trout are more prolific but produce smaller ova.

The females of our collection showed from 2 to 5 annuli on their scales but egg counts did not seem to show significant variation between the different age groups, although Needham (1938) reported that in brook trout, "The number of eggs depends naturally upon the age of the fish." In our sample one 2-year-old brown trout had 1,238 eggs; 18 three-year-olds averaged 1,383 eggs; 17 four-year-olds, 1,155 eggs; and 4 five-year-olds, 1,279 eggs.

Old eggs, or eggs apparently held over from the previous year, were present in 50 per cent of the females studied. The numbers ranged from a single egg to 71 per female, with an average of approximately 5 old eggs per fish.

Measurements of diameter were made of eggs obtained from 31 females. The average diameter was 4.94 millimeters. The size of the eggs in this sample could not be correlated with the size or age of the fish or the number of eggs produced.

Table 4.—Size, weight, age, condition, and weight of the gonads of 15 Madison River male brown trout

[Averages are given in the bottom row]

Age (number of annuli)	Standard length (inches)	Total length (inches)	Weight (ounces)	*K*	Weight of testes (grams)
4	11.75	13.25	10	0.629	8.6
2	12.00	13.50	16	0.952	13.5
4	12.25	13.50	14	0.833	5.2
3	12.50	14.25	16	0.810	8.9
4	12.75	14.25	18	0.911	8.9
4	12.75	14.75	16	0.810	4.9
5	13.25	15.50	20	0.786	6.1
4	13.50	15.00	20	0.867	8.0
4	13.75	15.25	20	0.825	8.1
4	13.75	15.50	20	0.786	13.0
5	14.00	16.25	22	0.750	13.1
3	14.25	16.25	20	0.682	7.4
3	14.50	16.00	20	0.715	7.5
4	14.75	16.50	24	0.782	14.3
5	15.38	17.12	28	0.817	16.0
3.9	13.41	15.10	19	0.797	9.6

Measurements of Testes

Only 15 males were studied. Their body weights and lengths and gonad weights are given in Table 4. This small sample shows no correlation between the size or condition of the fish and the weight of the testes. The testes averaged 9.9 grams, or 1.7 per cent of the body weight. The lack of correlation may be due to the inadequate sample or to the different degrees of "ripeness." There is no reason to be-

lieve from this sample that the age of the fish has any bearing on the weight of the testes.

A summary of this paper may be found in the abstract.

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FISH POPULATIONS IN THE BACKWATERS OF WHEELER RESERVOIR AND SUGGESTIONS FOR THEIR MANAGEMENT[1]

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ABSTRACT

During the past 3 years, several methods have been used in an effort to determine the standing crop of fish and the relative abundance of the different species in the fish population of Wheeler Reservoir. In addition to a census of sport and commercial fishing, gillnets, set lines, seines, fyke nets, and rotenone have been used to sample the fish population. Among the methods used, poisoning with rotenone has proven to be the most effective. When sampling the fish population by this method, areas of the reservoir which were suitable for study were shut off by means of a barrier seine before the rotenone was applied. This procedure made it possible to determine the total fish population and the relative numbers and weights of each species without allowing the poison to spread or fish to migrate to or from the area. Three plots having a combined area of 12 acres were treated in this way.

It was found that of the total weight of fish taken in the three areas, game fish comprised from 2 to 4 per cent; panfish 7 to 19 per cent; food fish 3 to 6 per cent; and coarse fish 73 to 85 per cent. Coarse fish, such as carp, buffalo, and shad, were dominant in the population of all areas. It is concluded that the desirable species, such as black bass, must be encouraged in all possible ways and the coarse species controlled by all means at hand, if game fishing is to be maintained. As an experiment, it is planned to screen off an area having a narrow connection with the main reservoir so that all fish can be removed by the use of rotenone and the area restocked with desirable species. It is blieved that by removing the coarse species which now comprise about 73 to 85 per cent of the total weight of fish present, the total productive capacity of the water will be used in the production of desirable species and the yield of these species will be greatly increased, which will greatly benefit sport fishing.

INTRODUCTION

The formation of a chain of multiple-purpose reservoirs along the Tennessee River and its tributaries, by the Tennessee Valley Authority, has created extensive areas of new fishing water and has produced new problems for the fishery manager. Investigations conducted by the Biological Readjustment Division of the Authority indicate that each reservoir and its fish population pass through a cycle of development during the first few years of impoundment, and that one of the most important problems in the sustaining of sport and commercial fishing in the lower run-of-the-river reservoirs is the maintanance of a desirable balance among the different species comprising the total population. There are indications that the species composition of the fish population changes from year to year and that the trend is toward a

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decrease in the number of black bass and an increase in the number of crappies during the third and fourth years of impoundment. Thereafter, as the reservoirs become older, there probably is a progressive decrease in black bass and crappies, with an increase in the less desirable coarse species. Although the game fishes and panfish seem to have cycles of abundance, the high points of the cycles appear to be lowered in favor of a corresponding increase in the less desirable species. While some suggestions can be made for counteracting this tendency, no tried and sure methods are at hand for solving the problem. Its solution is somewhat complicated by the necessity to change water levels due to the navigation, power, flood control, and malaria-control programs, and by the fact that the reservoirs are new and the environmental conditions are changing rapidly.

A knowledge of the standing fish population, the total removal by fishing, and the relative abundance of the different species in the catch is necessary for an understanding and solution of the problem of controlling the relative abundance of the different species in the total fish population. In order to obtain this information, a census of sport and commercial fishing, yield studies, and fish population studies have been made. Although these studies have been conducted on all of the lower run-of-the-river reservoirs (Guntersville, Wheeler, Wilson, and Pickwick) there has been a concentration of effort on Wheeler. This paper, therefore, will be confined to a discussion of the studies made on Wheeler Reservoir.

During the past 3 years, seines, gill nets, set lines, fyke nets, and derris root have been used in an effort to determine the standing fish population and the relative abundance of the various species in Wheeler Reservoir. The species composition of the catches made by each of these sampling methods are shown in Table 1. Extensive collections were made by gill nets, set lines and seines during 1938, while fyke nets and derris was used in 1941. Each of these sampling methods has certain advantages and disadvantages. Due to the large number of stumps in the backwaters, it was possible to seine only in restricted areas. In addition, carp and catfish are difficult to seine, carp being especially successful in eluding the net. However, an average of 15 fish per 1,000 square feet were taken by seine, which is an average of 653 fish per acre. The gill nets were selective for the taking of gar and were ineffective for the taking of small fish. As a result, no information on the reproduction of the different species was obtained and few or none of several species were taken. Set lines were perhaps the most selective of the various sampling methods, as their catches consisted mostly of catfish and no insect feeding centrarchids, smaller fish, or plankton feeders were taken. Although the censuses of commercial and sport fishing are very valuable for indicating the relative abundance of the different species in the catch, as shown in Table 1, they give no idea of the abundance of the species not generally taken by the fishermen. In addition, like gill-net, seine, and set-line fishing,

Table 1.—A comparison of species composition of catches taken by different methods used for sampling the fish population of

Table 1.—A comparison of species composition of catches taken by different methods used for sampling the fish population of Wheeler Reservoir

Species	Gill nets[1]	Set lines[2]	Seining[3]	Hoop-net catch[4]		Rotenone studies[5]		Sport-fishing catch			Commercial catch—1940[9]
	Percentage of total number	Percentage of total number	Percentage of total number	Percentage of total number	Percentage of total weight	Percentage of total number	Percentage of total weight	Percentage of total number			Percentage of total weight
								1939[6]	1940[7]	1941[8]	
Acipenser fluvescens	0.29	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.64
Polyodon spathula	2.33	.....	0.03	.....	.....	.....	.....	.....	.....	.....	.....
Lepisosteus productus	12.54	1.28	0.03	1.31	5.75	0.23	3.24	.....	.....	.....	.....
Lepisosteus osseus oxyurus	46.94	.....	0.01	0.83	7.74	0.02	0.02	.....	.....	.....	.....
Amia calva	.....	6.41	0.03	0.04	0.09	0.03	0.35	3.05	0.61	0.12	0.59
Amphiodon alosoides	7.58	1.28	0.01	.....	.....	.....	.....	.....	.....	.....	.....
Dorosoma cepedianm	4.98	.....	21.30	6.51	3.93	27.35	33.40	.....	.....	.....	.....
Pomolobus chrysochloris	0.29	.....	0.48	0.07	0.14	0.04	0.05	0.05	.....	.....	.....
Buffalo	0.29	.....	4.67	1.86	3.86	1.03	14.47	.....	0.40	0.04	2.35
Carp suckers (*Carpiodes*)	1.46	.....	1.40	0.24	0.73	0.09	0.89	.....	.....	.....	.....
Other suckers	0.87	.....	1.43	0.75	1.29	.....	0.01	0.40	0.03	.....	.....
Cyprinus carpio	6.41	2.57	0.22	0.60	2.79	3.36	30.35	11.57	13.60	3.03	27.05
Other minnows	.....	.....	10.39	.....	.....	4.13	0.11	.....	.....	.....	.....
Ictalurus lacustris punctatus	2.92	46.15	0.19	0.16	0.11	0.04	0.16	1.17	0.23	0.15	6.37
Ictalurus furcatus	.....	14.10	.....	0.12	0.30	.....	.....	4.62	0.93	0.84	20.10
Pilodictis olivaris	0.58	12.82	0.01	0.83	16.85	.....	.....	4.94	1.82	0.55	34.94
All catfish	3.50	73.07	0.21	1.11	17.26	0.04	0.16	10.73	2.98	1.54	61.41
Bullheads	0.29	2.57	0.26	1.83	2.08	0.69	1.68	1.39	0.49	0.10	0.66
Esox niger crassus	0.29	.....	0.64	0.16	0.74	.....	0.01	0.50	0.18	0.09	.....
Fundulus olivaceus	.....	.....	0.58	.....	.....	.....	.....	.....	.....	.....	.....
Serranidae	.....	.....	0.26	0.86	1.45	0.12	0.11	3.08	1.88	0.81	.....
Stizostedion c. canadense	3.79	.....	0.09	.....	.....	.....	.....	0.41	0.14	0.06	.....
Percina caprodes caprodes	.....	.....	0.31	.....	.....	.....	.....	.....	.....	.....	.....
Other darters	.....	.....	0.25	.....	.....	.....	.....	.....	.....	.....	.....
Micropterus p. punctulatus	.....	.....	0.69	0.75	1.45	.....	.....	.....	.....	.....	.....
Huro salmoides	2.33	5.13	2.68	0.20	0.44	4.98	3.16	.....	.....	.....	.....
All black bass	2.33	5.13	3.37	0.95	1.89	4.98	3.16	24.60	18.14	8.58	.....
Chaenobryttus gulosus	.....	.....	1.04	0.07	0.05	0.43	0.20	.....	.....	.....	.....
Lepomis cyanellus	.....	.....	2.40	.....	.....	0.62	0.27	.....	.....	.....	.....
Lepomis m. macrochirus	0.58	.....	18.64	13.45	5.46	6.78	4.85	15.81	25.46	10.94	.....
Other sunfishes and fingerlings	.....	.....	14.52	0.35	0.13	48.79	3.13	0.49	0.18	.....	.....
Pomoxis nigro-maculatus	0.87	.....	0.96	23.73	17.88	0.19	0.48	.....	.....	.....	.....
Pomoxis annularis	3.50	.....	6.73	44.72	26.36	0.51	1.28	.....	.....	.....	.....
All crappies	4.37	.....	7.69	68.45	44.24	0.70	1.76	25.86	34.84	74.30	.....
Labidesthes s. sicculus	.....	.....	7.68	.....	.....	.....	.....	.....	.....	.....	.....
Aplodinotus grunniens	0.88	7.69	2.04	0.52	0.40	0.55	1.78	2.05	1.07	0.38	7.30

[1]Based on catch of 100 yards of gill net 6 feet deep fishing for 70 days.
[2]Based on catch of a 100 hook set line fishing for 24 days.
[3]Based on 16,940 fish collected from various parts of the reservoir by seining a total of 26 acres.
[4]Based on the catch from 178 net days of fishing.
[5]Fish taken from three plots having a combined area of 12 acres.
[6]Based on catch of 8,045 man-days of fishing.
[7]Based on catch of 10,662 man-days of fishing.
[8]Based on catch of 3,903 man-days of fishing in the first half of 1941.
[9]Data taken from a catch of 187,145 pounds of fish.

the commercial- and sport-fishing census gives no definite information on the standing population.

To overcome these difficulties, a barrier seine was devised in 1939 for shutting off restricted bays and narrow areas so they could be poisoned with rotenone and the total fish population determined. These barrier seines, which were made of strips of cotton sheeting 50 yards long and 90 inches wide, to which were affixed lead and float lines, served to keep the fish in the area treated during the poisoning operation and to prevent the rotenone from spreading outside of the enclosure and killing other fish. The barrier seines were left in place after poisoning until the rotenone had deteriorated, so that the fish migrating into the area would not be killed. Two small areas were studied in this manner in 1940. Studies in small plots did not prove successful, however, as the large fish were frightened from the area while the seine was being put in place and only those species living close to shore were obtained. In order to overcome this difficulty, areas of several acres, each having a narrow connection with the main reservoir, were studied in 1941. In selecting the areas to be poisoned, ponds joined to the reservoir by means of a ditch or slough and bays having connections with the reservoir which were not more than 60 yards across were chosen, as they were more easily shut off by the barrier seines.

Derris root, having a rotenone content of 5 per cent, was used for the poisoning. It was first mixed with water to form a paste, after which it was put in a large tank and diluted with water. This tank was then floated to any desired part of the plot being treated and the poison applied by means of sprinkling cans. Usually, fish began to come to the surface before the treatment was complete. Gizzard shad were the first species to be affected. Immediately after treatment there was a period of about an hour during which gizzard shad, carp, buffalo, and drum would struggle at the surface before they died and sank to the bottom. An effort was made to collect as many of the fish as possible while they were still at the surface, as they were then in good condition. After they sank to the bottom, they could not be collected until the gases formed by decomposition brought them to the surface. This process required 4 to 12 hours. Bluegills, sunfish, crappies, and bullheads were the last to come to the surface. Small *Gambusia* decomposed on the bottom without coming to the surface. Therefore, they have been omitted from the list of species taken by poisoning and the other sampling methods. All fish were sorted by species, counted, and weighed in groups of 4 to 100 or more. Large fish were weighed to the nearest ounce and small fish to the nearest one-quarter ounce.

Studies were made on three different plots having a total area of 12 acres. The area of these plots, the amount of rotenone used, and the number and weight of fish per acre from each plot are listed in Table 2. Railroad Pond and Sweetwater Slough are some distance from the main reservoir and each is connected to it by a narrow ditch. Both

Table 2.—Comparison of the areas treated with rotenone and their fish populations.

Item	Upper Railroad Pond	Powerline Slough	Sweetwater Slough
Date treated	May 28, 1941	August 5, 1941	June 4, 1941
Area treated	6.5 acres	1.1 acres	4.4 acres
Average depth	0.9 feet	2.4 feet	1 foot
Volume	5.75 acre-feet	2.69 acre-feet	4.4 acre-feet
Type of bottom	Clay Mud	Firm clay	Soft silt
Rooted aquatics	None	None	None
Water temperature	84° F.	94° F.	86° F.
Concentration of rotenone	1 to 10,000,000	1 to 6,000,000	1 to 12,000,000
Number of fish taken	17,643	23,026	10,162
Weight of fish taken	1,891 pounds	914 pounds	828 pounds
Fish per acre	2,714	20,933	2,309
Pounds of fish per acre	291.5 pounds	831 pounds	188.2 pounds

of these areas lose their water connection with the reservoir when the water elevation in the reservoir drops 2½ feet below the full or high water stage. Powerline Slough is connected directly with the backwater areas of the reservoirs. It is near the old river channel and fish have direct access to it. For this reason it is considered more representative of backwater conditions and its standing population should be more representative of that occurring in the majority of the backwaters than are the populations occurring in areas which are disconnected from the main reservoir at times of low-water stage. Like much of the other backwater areas, Powerline Slough becomes dry when the water in the reservoir is at its lowest stage during the winter drawdown. Sweetwater Slough becomes dry during periods of drought and was dry during the fall and early winter of 1940-1941. Its fish population entered with the high water which flooded the area during the early spring months of 1941. Although Upper Railroad Pond becomes disconnected from the reservoir, it does not become entirely dry and maintains a fish population from year to year with fish free to enter and leave during periods of high water. The number and weight per acre of the different species of fish taken in each of these three areas and the percentage of the total population which they represent are listed in Table 3.

Upper Railroad Pond

When treated late in May, Upper Railroad Pond had an area of 6.5 acres and an average depth of less than 1 foot. Except for being separated from the main reservoir during periods of low water it is a mud-bottom, stumpy area fairly typical of the Wheeler Reservoir backwaters. Carp, shad, buffalo, and gar comprised 85 per cent of the total weight of fish taken in this area and ranked in abundance in the order named. Although black bass were numerically the most abundant species due to the large number of fingerlings, game fish comprised less than 4 per cent of the total weight of fish taken. While panfish were numerically quite plentiful they accounted for less than 7 per cent of the total weight of fish. Gar were more numerous than had been anticipated, as 166 were taken. Dogfish were not as common as

Table 3.—Numbers and weights per acre of the various fishes in the backwater areas of Wheeler Reservoir, and the relative abundance of the different species expressed as a percentage of the total number and weight of fish taken

Species	Upper Railroad Pond				Powerline Slough				Sweetwater Slough				Sweetwater Slough[3]	
	Average per acre		Percentage of total number	Percentage of total weight	Average per acre		Percentage of total number	Percentage of total weight	Average per acre		Percentage of total number	Percentage of total weight	Percentage of total number	Percentage of total weight
	Number	Weight			Number	Weight			Number	Weight				
Lepisosteus osseus oxyurus	....	....	....	....	5.5	0.2	0.03	0.02	....	....	....	....	....	....
Lepisosteus productus	25.5	21.1	0.94	7.24	33.6	21.3	0.16	2.57	....	....	....	....	....	....
Amia calva	0.9	0.6	0.03	0.21	1.8	2.9	0.01	0.35	4.3	1.1	0.18	0.60	....	....
Dorosoma cepedianum	520.9	82.5	19.08	28.34	2,155.4	230.0	10.30	27.68	343.8	53.4	14.89	28.40	36.40	33.38
Dorosoma cepedianum (fings.)	192.6	0.1	7.09	0.04	3,885.5	70.9	18.56	8.53	....	....	....	....	....	....
Pomolobus chrysochloris	....	....	....	....	10.9	0.6	0.05	0.08	....	....	....	....	....	....
Megastomatobus cyprinella	....	....	0.57	....	31.8	64.9	0.15	7.81	0.2	0.2	0.01	0.12	0.74	2.44
Ictiobus bubalus	....	....	1.79	....	10.9	7.5	0.05	0.91	0.2	0.1	0.01	0.07	0.28	1.00
Ictiobus niger	....	....	2.35	....	93.6	60.4	0.45	7.28	3.6	2.4	0.16	1.26	5.70	13.45
All buffalo	128.0	53.8	4.71	18.50	136.3	132.8	0.65	16.00	4.0	2.7	0.18	1.45	6.72	16.89
Carpiodes cyprinus	0.1	0.1	....	0.03	21.4	11.1	0.10	1.33	1.1	0.5	0.05	0.25	....	....
Minytrema melanops	0.1	....	....	0.01	....	....	....	....	....	....	....	....	....	....
Moxostoma breviceps	....	....	....	....	0.9	0.1	....	0.02	....	....	....	....	0.04	0.24
Cyprinus carpio	132.3	88.8	4.87	30.51	228.1	226.6	1.09	27.28	77.5	78.5	3.35	41.73	6.17	20.41
Cyprinus carpio (fingerlings)	113.2	0.6	4.17	0.19	320.9	2.5	1.54	0.30	....	....	....	....	....	....
Other minnows	1.8	....	0.07	0.03	1,064.5	1.3	5.08	0.16	6.8	0.2	0.28	0.12	0.20	....
Ictalurus lacustris punctatus	....	....	....	....	10.9	2.1	0.05	0.25	....	....	....	....	....	....
Ameiurus melas catulus	2.0	1.2	0.07	0.41	17.3	0.1	0.08	0.02	1.4	0.2	0.06	0.10	0.75	1.20
Ameiurus nebulosus marmoratus	7.1	3.0	0.26	1.04	10.9	0.8	0.05	0.10	39.3	3.9	1.70	2.08	0.59	1.04
Ameiurus n. natalis	12.6	6.3	0.46	2.18	1.8	....	0.01	0.01	78.2	6.5	3.39	3.45	0.04	0.08
Bullhead (fingerlings)	7.2	....	0.27	....	....	....	....	....	....	....	....	....	....	....
Esox niger	0.8	....	0.03	....	....	....	....	....	0.7	0.1	0.03	0.05	....	....
Percina caprodes caprodes	0.1	....	....	....	....	....	....	....	....	....	....	....	0.04	....
Lepibema chrysops	2.0	0.2	0.07	0.05	21.8	0.5	0.10	0.07	....	....	....	....	0.10	....
Morone interrupta	....	....	....	....	7.3	0.6	0.03	0.08	0.7	0.1	0.03	0.06	0.14	0.08
Huro salmoides	19.2	9.8	0.70	3.37	41.8	19.0	0.20	2.29	43.6	4.1	1.89	2.17	3.07	8.64
Huro salmoides (fingerlings)	785.2	1.3	28.92	0.44	356.3	7.0	1.70	0.85	46.6	0.1	2.02	0.06	0.75	0.02
All black bass	804.4	11.1	29.63	3.81	398.2	26.0	1.90	3.14	90.2	4.2	3.91	2.23	3.82	8.66
Chaenobryttus gulosus	4.2	0.2	0.15	0.07	58.1	0.5	0.28	0.07	49.3	1.9	2.14	1.00	0.55	0.16
Lepomis cyanellus	14.0	0.4	0.51	0.13	13.6	....	0.07	0.01	133.9	3.1	5.80	1.65	0.39	0.12
Lepomis humilis	170.0	2.1	6.25	0.74	616.3	2.5	2.94	0.31	15.0	0.2	0.65	0.11	....	....
Lepomis m. megalotis	....	....	....	....	....	....	....	....	0.5	....	0.02	0.03	....	....
Lepomis microlophus	152.7	1.9	5.63	0.65	....	....	....	....	502.5	9.8	21.76	5.19	2.48	1.48
Lepomis m. macrochirus	327.7	10.2	12.07	3.51	....	....	....	....	957.7	21.0	41.47	11.15	25.20	16.09
Unclassified sunfishes	....	....	....	....	[1]473.6	[1]32.3	[1]2.26	[1]3.90	....	....	....	....	....	....
Sunfish fingerlings	53.4	....	1.97	....	11,154.5	24.5	53.29	2.95	[2]....	[2]....	[2]....	[2]....	16.08	0.12
Pomoxis nigro-maculatus	9.2	1.2	0.34	0.41	40.0	5.0	0.19	0.60	1.1	0.1	0.05	0.07	0.04	0.04
Pomoxis annularis	26.3	3.6	0.97	1.24	106.3	13.2	0.51	1.60	....	....	....	....	0.04	0.04
Aplodinotus grunniens	5.0	1.4	0.18	0.49	136.3	21.4	0.65	2.58	1.3	0.5	0.06	0.26	0.04	0.04
Labidesthes s. sicculus	0.1	....	....	....	0.9	....	....	....	....	....	....	....	....	....

[1]Bluegills and a few redear sunfish.
[2]Fry were newly-hatched and too small to collect.
[3]This is a study to determine migration into a fishless area, and is not a population study.

had been expected as only one young of the year and two yearlings were found. Gizzard shad were very abundant and represented over one fourth of the total weight of the fish taken. Because the shad fry were small and decomposed rapidly it is possible that many of them were missed although a special effort was made to secure the young of all species by picking them up first.

Of the three species of buffalo found in the area, *Ictiobus niger* was the most abundant, but the largemouth buffalo, *Megastomatobus cyprinella,* averaged the largest. No buffalo fry were found. Carp suckers were rare, and only one species, *Carpiodes cyprinus,* was taken. *Carpiodes carpio* appears to stay in deeper water. Suckers and minnows, other than carp, were rare. Several large carp were taken, but age-groups I and II were dominant. As the water was shallow, no catfish were taken but bullheads were quite abundant. Only fingerlings of *Esox niger* were found.

In addition to the fingerlings, 125 largemouth black bass 1 year old or older were taken. About 60 of these were larger than the legal size limit of 11 inches and six were quite large, varying in weight from 2¼ to 4¾ pounds. A total of 5,104 fingerling largemouth black bass 1¼ to 2 inches long were found. As this is a population of over 785 per acre, it represents a very good hatch and indicates that natural reproduction can be quite successful. Although this production is not as large as that attained in hatcheries, such a production if uniform over the reservoir would supply over 52 million fingerling largemouth bass at a very small cost to the public. The ratio of fingerlings to legal-size largemouth black bass in this area was 85.1 which indicates stocking would have to be heavy in order to appreciably increase the number of adults. Among the sunfishes ,the bluegill ranked first in abundance and size. The orange spotted sunfish, *Lepomis humilis,* never attains a large size and those taken varied in length from 1½ to 2¾ inches. As indicated in Table 3, this species is more abundant than the more desirable redeared sunfish, *Lepomis microlophus.* Not all the sunfish had spawned at the time of poisoning and any fry present were so small it was practically impossible to collect them. The abundance per acre of each of the species of sunfish is shown in Table 3.

Labidesthes s. sicculus	0.0	0.1	....	1.4	....	0.16	....	0.49	136.3	0.9	21.4	....	0.65	....	2.58	....	1.3	....	0.5	....	0.06	....	0.26	....	0.04	....

[1]Bluegills and a few redear sunfish.
[2]Fry were newly-hatched and too small to collect.
[3]This is a study to determine migration into a fishless area, and is not a population study.

Powerline Slough

The fish population in Powerline Slough was the largest and most varied of those studied as it averaged 20,933 fish weighing 831 pounds per acre. It was also the only area in which long-nose gar, *Lepisosteos osseus oxyurus,* were taken; however, only young-of-the-year were found, while both adults and young of the short nose gar, *Lepisosteos productus,* were common in all the areas studied. It would therefore appear that the long nose gar prefers to be over deeper water. The fingerling long-nose gar were 5½ to 7 inches long, and those of the short-nose gar 2 to 2¼ inches. As these are smaller than the fingerling

of the short-nose gar taken in Upper Railroad Pond in May, it must be that the short-nose gar spawns twice or has a long spawning season.

Gizzard shad were several times more abundant in this area than they were in other areas, and they were dominant in weight. Although gizzard shad are valuable as forage fish for the game species, as pointed out by Cooper (1936), it is believed that they may become too plentiful. Large gizzard shad were very numerous in this area and they averaged larger than most of the fish for which they are supposed to serve as food. In addition, they are largely plankton feeders and compete directly with the young game and panfish for food. Although a great deal of plankton occurs in our waters, it is conceivable that over 6,000 gizzard shad foraging in an acre of water would limit the food supply for the young game fish. In such situations gizzard shad probably limit rather than increase the game and panfish yield. Under such conditions the large population of gar, some 39 per acre in this area, would be a help and not a hindrance to the production of game and panfish, as the chief food of the gar in this section is gizzard shad.

As in all other areas studied in 1941, *Ictiobus niger* was the most abundant species of buffalo. In 1938, however, *Ictiobus bubalus* was the most abundant species of buffalo in the backwaters of the reservoir. *Ictiobus bubalus* has therefore been replaced in importance by *Ictiobus niger* since that time. This change is probably due to the lake conditions produced by impoundment because in the South, as Canfield (1922) has pointed out, *Ictiobus bubalus* is predominantly a river form and *Ictiobus niger* is a lake form. *Megastomatobus cyprinella* averaged the largest of all buffalo taken and several individuals weighed over 4 pounds. No buffalo fry were found, but two distinct size groups of carp fingerlings were taken. The largest group average about 85 millimeters long and is probably of the same age as the carp fingerlings taken in Upper Railroad Pond in May. The smaller group varied 20 to 40 millimeters in length and was much more abundant, having a ratio of 9:1 to the larger size group. This second brood was probably spawned during the first part of July when the reservoir rose 5 feet and the water moved into the marsh and terrestrial vegetation. During this period, activities similar to those noted during spring spawning were observed. These observations indicate that either carp spawn twice or they have a long spawning season. Several carp weighing between 4 and 5 pounds were taken and although the carp comprised over 27 per cent of the total weight of the fish, they ranked second in total weight to the gizzard shad, which averaged 301 pounds per acre.

Many young fish and fingerlings were taken in Powerline Slough. Warmouth bass fingerlings averaged 30 millimeters, orange spotted sunfish 45 millimeters, white bass 75 millimeters, drum 80 millimeters, bullhead fingerlings varied from 15 to 75 millimeters, channel catfish fingerlings from 120 to 170 millimeters, and bluegill and red eared sunfish fingerlings averaged 30 millimeters in length. The bluegills were very abundant, averaging well over 11,000 per acre. The ratio of fingerlings to legal-size (4½-inch) blue-gills was 272:1. With natu-

ral reproduction at this rate, it is not believed that stocking is required or that it would be beneficial. If the ratio of young to adults were maintained at this level throughout the reservoir, it would require a planting of over 18 million fingerlings about 1 inch in length to increase the number of legal-size bluegills 1 to the acre, that is, from 45 to 46 legal-sized fish per acre. The largest bluegill taken was just under 7 inches. The largest largemouth black bass found in the area weighed 2 pounds 2 ounces, and there were 14 legal-sized bass in all. The fingerling largemouth bass averaged about 4 inches long and numbered 356 per acre. The ratio of fingerlings to legal-sized largemouth bass was 28:1.

Sweetwater Slough

All fish present in Sweetwater Slough migrated into the area during the high-water period in the spring of 1941, and those taken represent only the fish which remained after the water receded. This condition probably accounts for the somewhat different composition of the fish population and the smaller poundage of fish per acre (Table 3). After the poisoning operations were completed, a dam was placed in the ditch connecting Sweetwater Slough with the reservoir. The slough became completely dry by the first of July. When the reservoir level raised in July the dam was removed and water allowed to flow into the area for 48 hours. The ditch was then closed and the area again treated with rotenone to determine the number of fish which had migrated into the area. It was found that during this period a total of 2,544 fish weighing 624.6 pounds had migrated into the slough through the ditch, which is some 10 to 12 feet wide and 2,350 feet long. The average migration was 53 fish per hour. The species composition of the fish population which migrated into the slough and the percentage which each species comprised of the total weight are shown in Table 3. Shad, carp, and buffalo entered the area in large numbers. While shad and buffalo were found to be more abundant than at the time of the first poisoning, carp did not represent such a large portion of the total weight of fish taken. This study indicates that largemouth black bass are among the first fish to move into the backwater areas when the water rises and one of the first to leave when it drops. In the first poisoning only two legal-sized largemouth bass were found, but in the second poisoning over 50 were taken and they represented a considerably larger portion of the total weight of fish taken. Fewer adult sunfish were found at the second poisoning, but they averaged larger in size. Many more sunfish fingerlings were also taken at the second poisoning as it was later in the season.

Discussion

A comparison of the three areas studied shows that game fish were numerically most abundant in Upper Railroad Pond. This is due to the large number of fingerling largemouth black bass which averaged 785 per acre. Although fingerling largemouth bass were not numeri-

cally so abundant in Powerline Slough, it is believed they represented almost as good a hatch, as they were twice as long and almost half as abundant as the fingerlings taken in Upper Railroad Pond in May. Fingerlings were not numerous in Sweetwater Slough. Game fish comprised only 2.3 to 3.9 per cent of the total weight of the fish population in the three areas, while the coarse species made up 73 to 85 per cent. Coarse fish were numerically most abundant in Upper Railroad Pond and least abundant in Sweetwater Slough. Panfish comprised 6.7 to 19.2 per cent of the total weight of fish in these areas and were most abundant in Sweetwater Slough where they made up 72 per cent of the total number of fish taken. In general, panfish were present in much larger numbers than game fish. Food fishes, bullheads, and drum were not abundant but were most numerous in Sweetwater Slough where they comprised about 5 per cent of the population. Coarse fish were dominant in the population of all the areas.

Although it is impossible to apply the methods used by Eschmeyer (1938) on small Michigan lakes to the large T.V.A. reservoirs, it is believed that rotenone can be used to advantage in certain areas of the reservoir for the management of fish populations. Areas having narrow connections with the reservoir can be screened so the fish cannot enter or leave them. By destroying the resident populations in such areas, it would be possible to stock only desirable species and thus utilize the total productive capacity of the area for the production of valuable game fishes and panfish. By eliminating the coarse fish, which now constitute 72 to 85 per cent of the total weight of fish present in this area, it should be possible to greatly increase the yield of the valuable species, since the standing crop remains more or less constant regardless of changes in the composition of the populations, as pointed out by Thompson and Bennett (1938). There are several such areas in Wheeler Reservoir which can be treated in this way and it is planned to carry on such studies in the near future.

Because the use of rotenone takes all of the fish present, regardless of species, it is considered to be the best of the sampling methods listed in Table 1. In addition, it serves as a means for determining and comparing the accuracy of each of the other sampling methods. In making these comparisons, however, the limitations of this method must be kept in mind. Foremost is the fact that there are certain species which are rarely found in shallow water. The catfishes prefer fairly deep water and are seldom found in the shallow backwaters, and the Hiodontidae are open-water forms rarely found in protected areas. Also, most of the crappies migrate to deeper water in May and early June and do not return to the shallow backwaters until fall. This fact is clearly shown by a comparison of the hoop-net take with that of the rotenone studies. Since 1938 there have been certain changes in the relative abundance of several species which must be taken into consideration. In 1938 catches by gillnet, which are especially proficient in the taking of gar, indicated that long-nose gar were more abundant

than short-nose gar, while the hoop net and poisoning studies made in 1941 show that the relative abundance of these two species is now reversed.

Although this apparent change in relative abundance may be due largely to the preference of the short-nose gar for the shallow water, it is believed that this species has become comparatively more abundant since impoundment. As indicated by the census of the sport catch, largemouth black bass have declined in the catch each year while the crappie have increased. There is also a tendency for the black crappie to replace the white crappie in these areas. The seining records for 1938 showed the white crappie to be about seven times as abundant as the black crappie, while the hoop-net and rotenone studies of 1941 show them to be only two to three times as abundant. The catches made by sport fishermen confirm this shift in species of crappie. Drum are reported by the fishermen to be decreasing in the lower portions of the reservoir, due to the destruction of their chief food, clams and snails, by the silting over of the rock and gravel bottoms in the deeper water areas. Carp are considered to be increasing in all areas.

A comparison of the different sampling methods listed in Table 1 indicates that set-line fishing is the poorest method. Although the gill nets took a greater variety of species, they were selective for the gar and did not give any index of the occurrence of natural reproduction or the relative abundance of the young fishes. Seining compared favorably with the poisoning studies and, with the exception of carp, secured a good sample of the fish found in the shallow areas. Seining is superior to fyke netting in shallow areas as it takes a better sample of the shad and captures small fish, minnows, fry, and fingerlings, thus giving a more adequate idea of the total population and the success of natural reproduction. Hoop nets, on the other hand, can be used in deeper water and though they tend to be selective for crappie and fail to take shad and carp in proportion to their occurrence in the environment, they are more effective in securing the large game fish and panfishes, as well as catfish and other open-water species. Hoop netting and seining are both inferior to the poisoning method, as they do not give an idea of the number and weight of fish per acre or take all fish according to their relative abundance. However, correction factors might be worked out for the various methods of sampling so that estimates of the total population could be made. If this were done, very small mesh hoop nets would have to be used or they would not capture the small fish which the poisoning investigations have shown to be numerically dominant in the fish populations. It is believed that the poisoning of selected plots by the use of rotenone and a barrier seine is the cheapest and most efficient method of sampling to determine the total fish population and the relative abundance of the different species comprising the population of the backwater areas. If used in conjunction with some effective method of sampling the

deep-water areas, the two methods would furnish the data on fish populations needed for fisheries management.

Although a census of sport and commercial fishing is of little value for indicating the relative abundance of the different species in the fish population or the total standing crop, it does show the relative abundance of the different species in the catch and the trend of the catch from year to year. When the species composition of the catch made by sport and commercial fishing is compared with the actual composition of the total population, as indicated by the rotenone studies, facts of importance to fisheries management are brought out. Dogfish and carp were taken by the commercial fishermen in almost the same proportion as they occurred in the backwaters, while the catch of buffalo fell below the relative abundance of this fish in the environment (Bryan and Tarzwell, 1941). Catfish and drum comprised a much larger proportion of the commercial catch than they did of the total population secured by poisoning, while bullheads were less abundant in the catch than in the population. These facts were probably due to the fact that the rotenone studies were confined to relatively shallow water.

A comparison of the sport-fishing catch for 1939-1940 and 1941 (Tarzwell, 1941) with the fish population indicated by the poisoning investigations (Table 1), reveals that there are several species which are very abundant in the fish population but are absent or poorly represented in the sport catch. Shad, carp, buffalo, and gar make up about 32 per cent by number and 82 per cent by weight of the total fish population, whereas during the past 3 years they have comprised only 2 to 14 per cent of the total sport catch. Conversely, the largemouth bass have made up a much larger proportion of the sport catch than they represented in the total fish population. If fishing is at all heavy, such a situation cannot exist for long if largemouth bass fishing is to be maintained. The result is clearly shown by the census of sport fishing, which indicates that the proportion of largemouth bass in the total catch declined from about 25 per cent in 1939 to 9 per cent in 1941. Sauger and white bass have also been relatively more abundant in the catch than they are in the population, and they have also declined in the catch. While largemouth bass have declined in the catch, crappies have increased greatly. This replacement of largemouth bass by crappies may be due in part to the greater demand for largemouth bass and its better "biting" qualities. The dominance of crappies over largemouth bass was noted by Thompson and Bennett (1938) in their studies on small impoundments in Illinois.

As pointed out by Thompson, Bennett, and Parr (1940), intensive fishing for certain desirable species tends to relieve the competition on the less desirable species. In the T.V.A. reservoirs, where there is a mixed population and where the conditions more or less favor the coarse species, such as carp and buffalo, intensive year-round fishing for largemouth black bass and the protection of the rough fishes by the

prohibition of netting can result only in the reduction of the desirable species and the increase of the coarse species. That this process is well along in Wheeler Reservoir is indicated by the poisoning studies which show that carp, buffalo, and shad dominate the fish population. Once the coarse species have replaced the desirable species it will be difficult to restore them because the carp, buffalo, and shad compete directly with the young of the game fish for space and food. Further, they root up the bottom, destroy aquatic vegetation, roil the water, and thus interfere with the feeding of the game species which secure their food largely by sight.

Because it is very difficult to restore the relative abundance of game fish, once they have decreased in numbers and the coarse fish have taken their place, every effort of management in newly-impounded waters should be directed toward preventing the increase of the coarse species at the cost of the game species. Since the population and pressure of competition are low in newly-impounded reservoirs, there is a very high percentage of survival among the young of game fish and panfish during the first year. As pointed out by Tarzwell (1941), game fish attain the peak of abundance during the second year of impoundment.

These studies therefore indicate that for the proper management of these waters desirable species, such as largemouth black bass which have a tendency to decrease in numbers, should be protected and encouraged by closed seasons, stabilized water levels during the spawning season, and by every other means possible. Also, the undesirable coarse species which have a tendency to replace game fish should be controlled and their numbers reduced by netting, seining, or other methods. These management practices should be undertaken in new reservoirs immediately after or even before their impoundment, as they will be much less effective if the cycle of displacement is allowed to get under way before they are put into operation. It must be recognized, however, that control of the coarse species by commercial exploitation will depend on the creation and maintenance of a market for these species. Thus, even in the newly-created impoundments of the T.V.A., it is apparent that fishery management soon becomes intimately connected with technical and economic developments.

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PROPAGATION OF THE SILVERY MINNOW (*HYBOGNATHUS NUCHALIS REGIUS* GIRARD) IN PONDS

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ABSTRACT

The silvery minnow was propagated successfully in a shallow earthen pond, 0.15 acre in area, at the experimental hatchery at Cornell University. The silvery minnow spawns in late April and early May over a silt bottom and requires no aquatic vegetation. The males are identified by their yellow color and the presence of minute body tubercles. The pond was fertilized three times during the summer with cottonseed meal and freshly-cut timothy was scattered along the shallow borders of the pond at intervals. The fish were not fed. Breeding adults (68 females and 16 males) from Cayuga Lake were introduced during the spring of 1938. In late September 6,650 young silvery minnows were recovered from the pond, and had an average total length of 61 millimeters (range, 41-72 millimeters). The production per acre was approximately 44,000.

Several thousand of the minnows were retained in the same pond through a second summer at the end of which they had attained an average length of 80 millimeters (range, 65 to 89 millimeters). These fish matured and spawned during the spring of 1940 and by September the parent males had reached an average length of 82 millimeters (range, 76 to 87 millimeters) and the females an average length of 88 millimeters (range, 78 to 96 millimeters).

The silvery minnow is an important bait fish in central New York and is used early in May in angling for pickerel and northern pike and later in the season for the capture of yellow perch and smallmouth and largemouth black bass. It may be used as a forage minnow in the propagation of the black basses and gives promise of filling an important niche in the artificial culture of muskellunge where an early-breeding minnow is needed to provide food for the newly hatched young.

Data on the production of various bait minnows and forage fishes are desirable because of the probable future curtailment of the activities of commercial bait fishermen in public waters, as well as for possible use in fish-management and fish-cultural programs. Considerable information on some aspect of the bait-minnow and forage-fish problems is contained in the reports of Cooper (1935, 1936), Davis (1928), Hubbs (1933, 1936), Lord (1927), Markus (1934, 1939) and Radcliffe (1931). Investigations of a number of native and exotic species were undertaken several years ago at the Cornell Experimental Hatchery under the direction of the late Dr. George C. Embody, but the results of most of these experiments remain unpublished.

Studies on the propagation in ponds of the eastern silvery minnow, *Hybognathus nuchalis regius* Girard,[1] were begun in the spring of

[1]Hubbs and Lagler (1941, page 50) recognized, outlined the ranges, and defined eastern and western subspecies of *Hybognathus nuchalis*.

1938 after field studies on the life history of the species (published elsewhere in part; Raney, 1939) indicated that it might reproduce in ponds devoid of vegetation. The eastern silvery minnow is rather widely distributed and according to Hubbs and Lagler (1941) is found typically in larger, quieter waters from the Connecticut River and Lake Champlain drainages of New England and the Ottawa and Lake Ontario watersheds of Ontario southward, east of the Appalachians, to Georgia. Because of its early spawning period, prolificacy, and adaptability to pond culture it may prove useful in the culture of black basses (both *Micropterus* and *Huro*) and fill an important niche in muskellunge culture where small fry are needed urgently from about the middle of May to June 1. It is an important bait minnow and may be obtained in large numbers when concentrated on the breeding grounds. Both Markus (1934) and Raney (1939), have pointed out the undesirable depletion which results when this species is constantly seined by commercial bait fishermen during the spawning season.

The propagation experiments were carried on in a rectangular earthen pond, 0.15 acre in area. The depth varied from 4 feet near the outlet to 4 inches over a narrow shelf at the edge of the pond. The bottom was silt and lacked vegetation except for quantities of filamentous algae later in the summer. Moderate quantities of cottonseed meal were applied three times during May and June, and freshly cut timothy was thrown along shore several times during the summer. The pond was stocked with 68 females and 16 males which were secured at the south end of Cayuga Lake in late April, 1938. During the spawning season the males are easily recognized by their yellow coloration, by the presence of small tubercles on the body and fins, and by their smaller size. Females with eggs present a somewhat swollen appearance. Spawning occurs on a silt bottom which may be partly covered with detritus and partly decayed vegetation from the previous summer. Breeding usually occurs in late April and early May when the water temperature is from 13° to 20° C. Spawning was observed in this pond on April 18, 1941. After the yolk sac is absorbed the larvae rise singly to the surface, and in a short time gather in small schools, a behavior characteristic of the silvery minnow throughout life.

By June 20 the young silvery minnows averaged 31 millimeters in total length and on July 15, 45 millimeters. In late September, 1938, 6,650 young weighing 11,608 grams were removed. These fish averaged 61 millimeters in total length and ranged from 41 to 72 millimeters (Figure 1). Several hundred specimens not included in the above totals were removed during the summer. A number of other fishes made their way into the pond, presumably through muskrat holes and undoubtedly reduced the production still further. The estimated production was 44,000 individuals per acre. Markus (1939) reported a production of 35,200 per acre from a small number of breeders. His

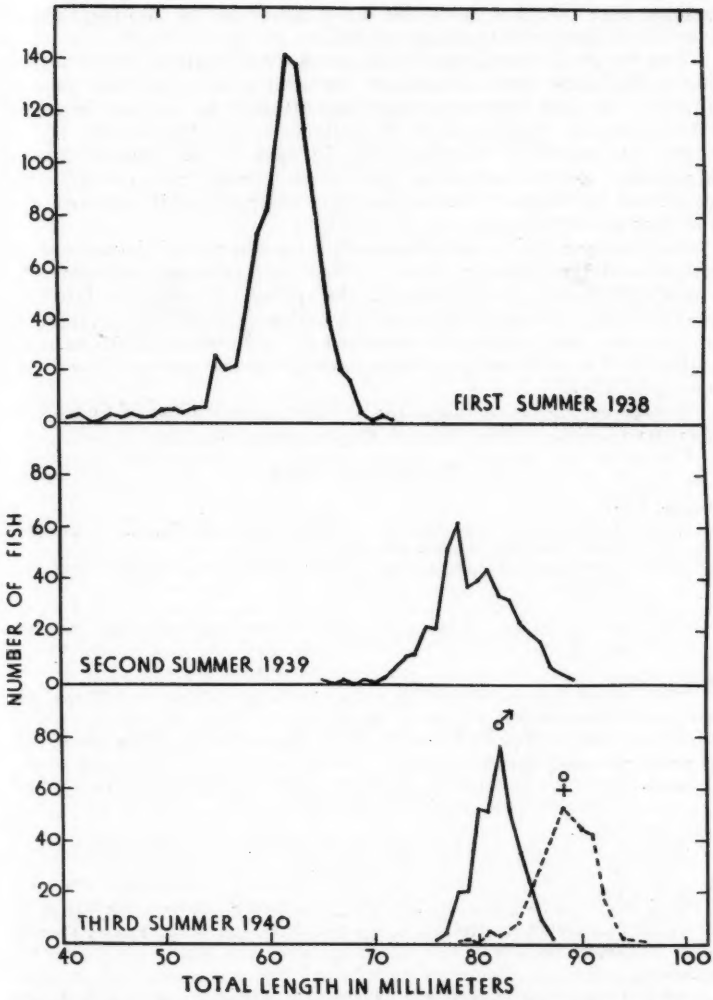

Figure 1.—Length-frequency distribution of the eastern silvery minnow taken in late September, at the end of their first, second, and third summers of life, from a pond at th Cornell Experimental Hatchery, Ithaca, New York. (The 1938 sample included 972 specimens, the 1939 sample 453 specimens and the 1940 sample included 462 males and 351 females.)

results were obtained with the same subspecies in Monroe County, New York, during the summer of 1935.

Two thousand young silvery minnows were retained, without feeding in the same pond throughout the winter and following summer (1939). By late September they had attained an average length of 80 millimeters (range, 65 to 89 millimeters). (See Figure 1.) A 5 per cent mortality occurred due, in part, to the depredations of kingfishers, several largemouth bass which entered from a neighboring pond, and to fungus. Several fish were observed partly covered with the fungus, *Saprolegnia*.

The silvery minnows were retained in the same pond throughout the winter and the summer (1940). They had attained maturity at 2 years of age and spawned during the spring of 1940. By late September, 1940, the males averaged 82 millimeters in length (76 to 87 millimeters) and the females averaged 88 millimeters (78 to 96 millimeters). The original progeny spawned for the second time in the spring of 1941.

The writer wishes to thank Dr. C. McC. Mottley for making available the facilities of the Cornell Experimental Hatchery.

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SOME OBSERVATIONS ON THE WINTER FEEDING HABITS OF BROOK TROUT FINGERLINGS IN RELATION TO NATURAL FOOD ORGANISMS PRESENT[1]

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ABSTRACT

At the Hunt Creek Experiment Station near Lewiston, Michigan, water was first admitted to a newly-excavated stream channel on October 16, 1940, after adult aquatic insects had apparently disappeared. The first bottom organisms to invade the new habitat, blackfly larvae, were observed 1 week later. It is concluded that these and subsequent invaders were drift-borne from natural areas upstream. On December 20, a square-foot bottom sample contained 187 organisms representing 8 species, with a volume of 0.20 cubic centimeters. On February 4, 1941, a sample contained 21 species and 1,535 organisms, with a volume of 1.575 cubic centimeters.

The section was first screened and drained down on January 18, 1941. At that time, 34 eastern brook trout (*Salvelinus fontinalis*) were removed, of which 22 were retained for stomach analysis. These fish had an average total length of 80.3 millimeters and an average weight of 5.0 grams. A comparison of stomach contents with bottom samples revealed that the percentage occurrences of food organisms in the brook trout stomachs and in the bottom fauna were not the same. For example, volumetrically, larvae and pupae of midges and blackflies made up 84.7 per cent of the diet but only 56.9 per cent of the bottom fauna; mayfly nymphs formed only 7.5 per cent of the diet but 24.8 per cent of the bottom fauna. The average number of food organisms per stomach was 252; the average volume of the contents of an individual stomach was 0.425 cubic centimeters. The average square-foot of bottom contained 1,114 organisms with a volume of 1.275 cubic centimeters.

During the fall of 1940, a series of three stream-channel diversions, delimited by bulkheads and screens, was excavated near the Hunt Creek Fisheries Experiment Station which is operated by the Institute for Fisheries Research of the Michigan Department of Conservation. By means of this construction it has been possible to split the flow of Hunt Creek into two channels, or to divert the entire flow through either the original or the new channel. The furthest downstream of the new diversions, hereafter designated as Section I-B, is 186 feet long and averages 6.1 feet in width at the water line. The average rate of flow, determined with the aid of a Bentzel velocity tube, is 1.5 feet per second, and the average depth is 8 inches, as normally regulated. The bottom is a mixture of sand and medium-sized gravel, and was without submerged vegetation at the time covered by this study. The immediate banks of the stream are low and marshy, and support a dense growth of *Carex*. About 20 feet from the water's edge, on one side, is a higher bank of morainal materials which supports an open

[1]Contribution from the Michigan Institute for Fisheries Research.

stand of aspen and Balm-of-Gilead. The stream is shaded only in early morning and late afternoon.

Water first flowed through Section I-B on October 16, 1940. Because adult aquatic insects had almost entirely disappeared before this date, the first appearance and subsequent increase of invading bottom organisms in the newly created habitat were observed with considerable interest, for it was realized that the invaders must, perforce, be supplied by drifting from natural habitats in the original channel upstream.

The first bottom organisms detected were larvae of a blackfly, *Simulium venustum*. They were first noticed in exceedingly small numbers on October 23, 1 week after the new channel was opened. The subsequent increase of organisms was very gradual, and for some time numbers were too scant to admit of accurate determination by the square-foot sampling method. A sample taken on December 20, however, yielded 187 organisms, divided among 8 species, and had a total volume of 0.20 cubic centimeters (Table 1). On January 24, 1941, a square-foot sample contained 19 species and 701 individuals, with a volume of 0.925 cubic centimeters (Table 2). On January 27, a sample contained 19 species, 999 organisms, and measured 1.325 cubic centimeters (Table 3). Another sample was taken near the head of the section on February 4. Here the occurrence of a large number of small mayfly nymphs (*Baetis vagans*) helped to raise the volume of the sample to 1.575 cubic centimeters. Twenty-one species comprising 1,535 individual organisms were taken (Table 4).

Such a rapid influx of bottom organisms into the newly created habitat was not expected. It should be emphasized that the channel was excavated after almost all adult aquatic insects had laid their eggs and perished due to the lateness of the season. The only adult aquatic

Table 1.—Square-foot stream bottom sample taken from Section I-B on December 20, 1940

Organism[1]	Number of species	Number of individuals	Volume (cubic centimeters)	Percentage of total volume
Ephemeroptera (Mayflies)				
Ephemerella invaria—N	1	12	trace	trace
Baetis vagans—N	1	3	trace	trace
Trichoptera (Caddisflies)				
Rhyacophila sp.—L	1	1	trace	trace
Hydropsyche sparna—L	1	1	trace	trace
Diptera (Midges, flies, etc.)				
Tipulidae—L	1	1	trace	trace
Chironomus modestus—L	1	91	0.125	62.5
Chironomidae—L	2	78	0.025	12.5
All above "traces" combined	....	....	0.025	12.5
Totals	8	187	0.200	100.0

[1]N = nymph; L = larva.

Table 2.—Square-foot stream bottom sample taken from Section I-B on January 24, 1941

Organism[1]	Number of species	Number of individuals	Volume (cubic centimeters)	Percentage of total volume
Annelida (Aquatic worms)				
Tubificidae	1	1	trace	trace
Ephemeroptera (Mayflies)				
Paraleptophlebia mollis—N	1	1	trace	trace
Ephemerella invaria—N	1	15	0.025	2.7
Baetis vagans—N	1	278	0.225	24.3
Plecoptera (Stoneflies)				
Leuctra tenuis—N	1	4	0.025	2.7
Allocapnia torontoensis—N	1	15	0.025	2.7
Isoperla sp.—N	1	1	trace	trace
Trichoptera (Caddisflies)				
Mystrophora americana—L	1	3	trace	trace
Rhyacophila sp.—L	1	4	0.050	5.4
Chimarrha aterrima—L	1	1	trace	trace
Hydropsyche sparna—L	1	1	trace	trace
Diptera (Midges, black flies, etc.)				
Rhaphidolabis sp.—L	1	2	trace	trace
Chironomus modestus—L	1	80	0.300	32.5
Chironomus modestus—P	1	14	0.100	10.8
Chironomidae—L	3	172	0.025	2.7
Simulium venustum—L	1	108	0.150	16.2
Hydracarina (Water mites)	1	1	trace	trace
Totals	19	701	0.925	100.0

[1]N = nymph; L = larva; P = pupa.

Table 3.—Square-foot stream bottom sample taken from Section I-B on January 27, 1941

Organism[1]	Number of species	Number of individuals	Volume (cubic centimeters)	Percentage of total volume
Annelida (Aquatic worms)				
Lumbriculidae	1	1	0.050	3.8
Tubificidae	1	7	0.025	1.9
Hirudinea	1	1	0.125	9.4
Malacostraca (Shrimp)				
Hyalella sp.	1	1	trace	trace
Ephemeroptera (Mayflies)				
Ephemerella invaria—N	1	9	0.025	1.9
Baetis vagans—N	1	242	0.200	15.1
Plecoptera (Stoneflies)				
Leuctra tenuis—N	1	8	trace	trace
Allocapnia torontoensis—N	1	23	0.050	3.8
Nemoura sp.—N.	1	10	0.025	1.9
Coleoptera (Water beetles)				
Stenelmis sp.—L	1	1	trace	trace
Trichoptera (Caddisflies)				
Rhyacophila sp.—L	1	6	0.050	3.8
Hydropsyche sparna—L	1	1	0.025	1.9
Diptera (Midges, flies, etc.)				
Rhaphidolabis sp.—L	1	2	0.025	1.9
Chironomus modestus—L	1	75	0.300	22.6
Chironomus modestus—P	1	31	0.175	13.2
Chironomidae—L	2	487	0.150	11.3
Ceratopogonidae—L	1	1	trace	trace
Simulium venustum—L	1	93	0.100	7.5
Totals	19	999	1.325	100.0

[1]N = nymph; L = larva; P = pupa.

insects seen along the stream after the opening of the channel were a few specimens of the late-emerging caddisfly, *Neophylax autumnus*. It is concluded, therefore, that the organisms revealed by the samples must have drifted into the area from upstream, either as eggs or as nymphs and larvae. This conclusion is favored also by the fact that relatively sessile, clinging forms such as case-making caddis larvae were of rare occurrence. In only one sample (Table 2) was a case-making caddis represented, and then by only three specimens. Surber (1937) wrote that when a West Virginia stream was scoured out by a flood in late August, the bottom fauna increased more than four-fold in 7 weeks. Moffett (1936), who reported on the recovery of bottom fauna in South Willow Creek, a high-gradient mountain stream in Utah which had been scoured out entirely by a cloudburst on August 7, listed the following figures: August 20, no organisms found; September 22, average number per square foot 152, average volume 0.30 cubic centimeters; November 11, average number per square foot 1,040, average volume 1.57 cubic centimeters; March 2, average number per square foot 803, average volume 1.79 cubic centimeters. The chief increase in both numbers and volume of the bottom fauna occurred

Table 4.—Square-foot stream bottom sample taken from Section I-B on February 4, 1941

Organism[1]	Number of species	Number of individuals	Volume (cubic centimeters)	Percentage of total volume
Turbellaria (Free-living flatworms)				
Planariidae	1	1	trace	trace
Annelida (Aquatic worms)				
Tubificidae	1	1	trace	trace
Malacostraca (Freshwater shrimp)				
Gammarus sp.	1	2	0.025	1.6
Ephemeroptera (Mayflies)				
Ephemerella invaria—N	1	23	0.025	1.6
Baetis vagans—N	1	699	0.450	28.5
Plecoptera (Stoneflies)				
Leuctra tenuis—N	1	7	.....	.....
Allocapnia torontoensis—N	1	10	.....	.....
Nemoura sp.—N	1	20	0.050	3.2
Isoperla sp.—N	1	1	.....	.....
Isogenus frontalis—N	1	1	0.075	4.7
Trichoptera (Caddisflies)				
Rhyacophila sp.—L	1	6	0.050	3.2
Hydropsyche sparna—L	1	2	0.050	3.2
Diptera (Midges, blackflies, etc.)				
Rhaphidolabis sp.—L	1	3	trace	trace
Chironomus modestus—L	1	49	0.225	14.3
Chironomus modestus—P	1	70	0.225	14.3
Chironomidae—L	3	590	0.200	12.7
Ceratopogonidae—L	2	3	trace	trace
Simulium venustum—L	1	142	0.200	12.7
Hydracarina (Water mites)	1	5	trace	trace
Totals	21	1,535	1.575	100.0

[1]N = nymph; L = larva; P = pupa.

during the first 7 weeks, although in both streams there may have been some oviposition by adult insects before the onset of winter. Moffett concluded that species having the shorter life cycles were the first to re-establish themselves, but considered that the action of the drift in transporting organisms was of great significance in the repopulation. He also noted a fact frequently observed in our own work, namely, that as winter progresses, the numbers of organisms per unit area generally decrease, but the volumes meanwhile increase; the growth of individual specimens more than compensates the reduction in numbers.

The rate of faunal influx in Section I-B is in good agreement with the recovery results mentioned above, despite the fact that the influx began more than 2 months later in the season than did the recovery in either of the streams discussed in the publications cited, thus ruling out almost entirely the possibility of colonization by direct oviposition. It is, therefore, quite certain that the rapid spreading of organisms in the new channel was due to the swift current of Hunt Creek, which must constantly dislodge and transport large numbers of bottom organisms.

On January 18, 1941, Section I-B was screened and drained down for the first time, and all the brook trout (*Salvelinus fontinalis*) occupying the area were recovered. Of the 34 brook trout present, 22 were retained for stomach analysis.[2] The size range was as follows: Standard length, 49 to 103 millimeters, average 66.8; total length, 59 to 132 millimeters, average 80.3; weight, 1 to 19 grams, average 5.0. The average coefficient of condition was calculated as 1.66.

A comparison of Tables 5 and 6 which summarize, respectively, the stomach contents of the 22 brook trout and the average of three square-foot bottom samples taken at about the same time reveals that the relative abundance of organisms on the bottom and in the stomachs of the brook trout were not the same. While aquatic Diptera (larvae of midges, blackflies, etc.) composed approximately 85 per cent of the total volume of stomach contents, they made up only about 57 per cent of the total volume of bottom fauna. Mayfly nymphs accounted for about 25 per cent by volume of the bottom fauna but for only 7.5 per cent of the total diet. Stonefly nymphs, which were third in importance in the bottom fauna with 6.5 per cent, ranked sixth in the brook trout diet, making up only 0.3 per cent of the total volume (although again ranking third numerically).

On a numerical basis alone, aquatic Diptera composed 80 per cent of the diet, but only 57.7 per cent of the bottom fauna. Mayflies made up almost 40 per cent of the bottom fauna but only 18.8 per cent of the diet. Stoneflies accounted for 3 per cent of the total numbers in the bottom, but entered the diet to the extent of only 0.6 per cent.

The low position of stoneflies in the diet, as compared with their

[2]The assistance of Mr. Edwin L. Cooper with the stomach analyses here reported is gratefully acknowledged.

Table 5.—Stomach analyses of 22 eastern brook trout from Hunt Creek, Section I-B
[Diet summarized by major groups of food organisms in order of importance on a volumetric basis]

Organism	Number of species	Number of individuals	Number of stomachs containing organisms	Most organisms in any stomach	Least organisms in any stomach	Average number of organisms in stomachs containing them	Percentage of total volume
Diptera (Flies and midges)	14	4,435	22	690	25	201.6	84.7
Ephemeroptera (Mayflies)	3	1,042	22	141	3	47.4	7.5
Annelida (Aquatic worms)	1	2	2	1	1	1.0	4.0
Trichoptera (Caddisflies)	7	20	13	5	1	1.5	1.6
Malacostraca (Shrimp)	1	3	2	2	1	1.5	1.6
Plecoptera (Stoneflies)	3	38	15	7	1	2.5	0.3
Hemiptera (Water bugs)	1	1	1	1	1	1.0	0.3

numbers in the stream, probably indicates that these nymphs, which normally occupy the under sides of stones, seldom come within the reach of feeding trout. Stoneflies as a group can hardly be unpalatable to trout. Muttkowski (1925), writing of the streams of Yellowstone National Park, Wyoming, stated that on the basis of the ". . . examination of hundreds of stomachs of trout, especially the cutthroat trout . . . it is evident that stoneflies . . . form about 90 per cent of the food . . ." Hazzard and Madsen (1933) found that stoneflies accounted for 16.5 per cent of the total food eaten by a series of 36 cutthroat trout taken from the streams of Teton Park, Wyoming, during the summer months.

The dominant stonefly mentioned in each of these reports was the large species, *Pteronarcys californica*, sometimes called the salmon-fly, which may attain a length of 2.5 to 3 inches. The stoneflies found in Hunt Creek range in size from *Allocapnia* and *Capnia*, only about 0.25 inch long, to *Isogenus frontalis*, whose length seldom exceeds an inch. The heavy utilization by trout of the large western species is,

Table 6.—Average of three square-foot bottom samples taken from Diversion Section I-B, January 24 to February 4, 1941, all from similar situations
[Organisms listed in order of importance on a volumetric basis. Numbers of individuals shown to nearest whole number unless lower than one.]

Organism	Number of individuals	Percentage of total volume
Diptera (Flies and midges)	643	56.9
Ephemeroptera (Mayflies)	422	24.8
Plecoptera (Stoneflies)	33	6.5
Trichoptera (Caddisflies)	8	5.9
Annelida (Aquatic worms and leeches)	4	5.2
Malacostraca (Freshwater shrimp)	1	0.7
Hydracarina (Water mites)	2	trace
Coleoptera (Beetles)	0.3	trace
Turbellaria (Flatworms)	0.3	trace
Totals	1,113.6	100.0

therefore, probably to be explained by the much greater size of the insect and possibly, also, by differences between the two species of trout in method of feeding.

It is shown in Table 7 that a single adult caddisfly, *Neophylax autumnus*, was found in one stomach. While members of this species generally emerge in late fall, stragglers have been seen along Hunt Creek during every winter month; and trout are apparently not unwilling to take surface food at this time.

Table 7.—Brook trout stomach analyses, Hunt Creek, Section I-B; based on 22 fish taken January 18, 1941

Organism[1]	Number of species	Number of individuals	Number of stomachs containing organisms	Most organisms in any stomach	Least organisms in any stomach	Average number of organisms in stomachs containing them	Percentage of total volume
Annelida (Worms)							
Lumbriculidae	1	2	2	1	1	1.0	4.0
Malacostraca (Shrimp)							
Gammarus sp.	1	3	2	2	1	1.5	1.6
Ephemeroptera (Mayflies)							
Ephemerella invaria—N	1	6	5	2	1	1.2	trace
Blasturus nebulosus—N	1	1	1	1	1	1.0	trace
Baetis vagans—N	1	1,035	22	141	3	47.0	7.5
Plecoptera (Stoneflies)							
Leuctra tenuis—N	1	1	1	1	1	1.0	trace
Allocapnia torontoensis—N	1	36	15	7	1	2.4	trace
Isogenus frontalis—N	1	1	1	1	1	1.0	0.3
Hemiptera (Water bugs)							
Corixidae—A	1	1	1	1	1	1.0	0.3
Coleoptera (Water beetles)							
Bidessus sp.—A	1	1	1	1	1	1.0	trace
Trichoptera (Caddisflies)							
Hydroptilidae—L	1	1	1	1	1	1.0	trace
Mystrophora americana—L	1	1	1	1	1	1.0	trace
Mystrophora americana—P	1	1	1	1	1	1.0	trace
Chimarrha aterrima—L	1	2	2	1	1	1.0	trace
Hydropsyche sparna—L	1	8	6	2	1	1.3	1.0
Limnephilidae—L	1	4	4	1	1	1.0	0.3
Neophylax autumnus—A	1	1	1	1	1	1.0	0.3
Brachycentrus americanus—L	1	2	1	2	2	2.0	trace
Diptera (Midges, blackflies)							
Tipulidae—L	1	12	8	5	1	1.5	0.3
Tipula sp.—L	1	3	1	3	3	3.0	1.0
Rhaphidolabis sp.—L	1	2	1	2	2	2.0	0.3
Chironomus modestus—L	1	596	22	174	1	27.0	27.5
Chironomus modestus—P	1	18	8	10	1	2.2	0.5
Chironomidae—L	3	380	20	47	1	19.0	1.9
Chironomidae—P	3	2	1	2	2	2.0	trace
Ceratopogonidae—L	1	1	1	1	1	1.0	trace
Simulium venustum—L	1	3,420	22	622	6	155.4	53.2
Chrysops sp.—L	1	1	1	1	1	1.0	trace

[1]N = nymph; L = larva; P = pupa; A = adult.

The question naturally arises as to whether the disparity between total bottom fauna and total food taken is to be explained on the basis of actual selection—expression by the trout of definite partiality for certain food organisms—or on that of availability. Hess and Rainwater (1939) recently proposed a calculation of ratios which they believe will supply a numerical measure of the dietary preferences of trout. Their method consists in dividing the ratios of organisms available and consumed. For example: ". . . if mayflies and stoneflies are available in a ratio of 2 to 1, respectively, and the numbers eaten by the fish are in the same ratio, there is an equal preference for each organism (mayflies $2/2 = 1$; stoneflies $1/1 = 1$); but if four times as many mayflies as stoneflies are eaten, the preference ratio becomes 2 to 1 in favor of the mayflies (mayflies $4/2 = 2$; stoneflies $1/1 = 1$)."

The authors continued: "The accuracy of this measure of preference, then, depends upon the accuracy of the methods we use for determining the number of organisms available and the number eaten by the fish." They devoted the remainder of their paper to the presentation and discussion of a commendable attempt to determine experimentally the rate at which certain natural food organisms are digested by brook trout at various water temperatures and left without support the thesis indicated by the title of their paper. The old question of how to measure availability was ignored, for it is palpably absurd to consider that all organisms found in bottom samples are equally available to trout. Although the authors made no suggestion on the subject, it would seem just as logical to conclude that their proposed method for measuring the food preference of trout is actually, instead, a plausible method for measuring availability. Thus if, as in the work reported here, aquatic Diptera and mayflies are present in the stream in a ratio of 3-2, and four times as many Diptera as mayflies are eaten, the availability ratio might be expressed as 2.65:1 in favor of Diptera. There is little ground for the assumption in this instance, that there was any significant disparity in the rate at which small, weakly-chitinized mayfly nymphs of the genus *Baetis* and aquatic Diptera as represented by large midge larvae and pupae and large blackfly larvae, were digested.

That the digestive rate of the trout from Section I-B was very low was clearly observed. The trout were collected at 2:00 p.m. and placed in a tub full of water. Not until 5:00 p.m. were they killed and their stomach contents removed. At this time, 3 hours after the fish were removed from the stream, many of the midge and blackfly larvae and one large aquatic annelid were still alive and sufficiently vigorous to crawl from the stomachs of the trout out through gullet and mouth, and creep about the tray in which they had been placed. Digestion in these fish must have approached a standstill. The retarding of the digestive rate, almost certainly the result of low water temperatures, obviously was not accompanied by a lack of appetite, for the stomachs were well-filled. However, it is questionable as to how much nutri-

tional benefit would accrue to fish from such feeding. Examinations of the entire alimentary tract of trout taken in winter have, on repeated occasions, demonstrated the presence, all through the intestine and near the vent, of soft-bodied, easily-digested food organisms still almost wholly intact. During severe cold weather, peristaltic movements of the gut may move food organisms through and out of the alimentary tract before they have been digested. It would seem advisable to examine this problem further. If the fish derives but little nourishment from natural feeding in cold weather, food supplies during the coldest part of the year would not be a critical factor in the success of trout.

From the detailed data of Table 7, it will be seen that the 22 stomachs contained a total of 5,541 specimens distributed among 32 species. The average number of food organisms per stomach was 252; the average volume of the contents of an individual stomach was 0.425 cubic centimeters. Thus, an average square foot of bottom contained three times the volume, and slightly over four times the number of food organisms occurring in the average brook trout stomach at the time of collection.

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FIELD EXPERIMENTS IN SELECTING THE MOST EFFICIENT TAG FOR USE IN HADDOCK STUDIES

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ABSTRACT

Field experiments made along the coast of Maine including 2,073 tagged haddock and 15.5 per cent recaptures have demonstrated that haddock caught by hook and line can be tagged successfully in water as deep as 30 fathoms. Three types of tags were tested: The modified Petersen disc, the bachelor button, and the internal anchor. The disc tag gave the highest initial returns, but the later recoveries were poorer. The bachelor-button tag appears to be the most efficient because of the value of the more protracted returns in estimating the rate of mortality, but it has certain mechanical defects to be corrected. The internal anchor tag gave the poorest returns owing to the early loss of the outside dangler which greatly reduced its visibility. This tag holds promise if redesigned as it appears to remain with the fish as long or longer than the button type. Returns are shown by size of fish and a breakdown of time at liberty is given for each type of tag.

METHODS OF CONDUCTING TRIALS

The release and subsequent recovery of marked fish has long been recognized as a useful tool in studying migrations and more recently for determining rates of mortality. However, the results of many such experiments have been limited by the lack of an efficient method of marking the individual fish.

Perhaps the best way to explain what is meant by an "efficient" tag is by comparing it to the definition of an "efficient" statistic. Many statistics can be used that may give consistent results but extract only a portion of the relevant information, while an "efficient" statistic should extract all of the information contained in the data. In the same way if a thousand fish are marked with a tag that remains on the fish for only a few months, repetition of the experiment may give consistent results indicating a certain degree of movement and a certain rate of mortality, but these results may be far from correct.

Preliminary trial of various types of tags by holding fish in live cars provides a time and effort-saving means of eliminating tags that are obviously inefficient. However, once the most promising tags have been selected there is no substitute for actual field trials. This conclusion proceeds partly from the fact that the success of a tagging experiment depends not on the number of marked fish retaken by the fishermen, but on the number of tags that are actually returned to the investigator with adequate data on the location and date of recapture, and on such other information as is needed for the particular experiment; and partly from the difficulty of reproducing natural environmental conditions in a live car.

Field trials, if properly designed, will not only yield information concerning the efficiency of various tags, but can be used to elicit at least as much of the usual information as any other tagging experiment. In the haddock experiments an effort was made to insure that the trial tagging experiments were carried out under the same field conditions that would obtain during any later and more extensive experiment.

William C. Herrington and assistants carried out preliminary live-car tests on tagged haddock during 1930-32. During 1932-33 experiments on tagged haddock were conducted in the field (unpublished data. Out of nearly a dozen types of tags tested in the live-car experiments, the most promising were the bachelor button, the modified Petersen disk, and the belly tag, most of which remained on the fish throughout the duration of the experiments. In the field experiments, 440 haddock caught by otter trawls on the offshore banks were marked with button tags and 82 with belly tags. No returns were reported. Later, haddock caught by line trawls fished from large commercial vessels were tagged; 259 with button tags and 101 with belly tags. From this experiment only one button-tagged fish was reported recaptured.

The above experiments gave rise to the supposition that the poor returns were due to mortality of the fish caused by handling. Accordingly, in 1933, tagging was tried from a small, one-man line-trawl boat in relatively shallow water off the Maine coast. Out of 332 marked with button tags and 117 with belly tags, 26 were returned. Owing to lack of funds and personnel, experiments were discontinued temporarily.

In 1938, the experiments were resumed by the author with two main objectives, first to determine the most efficient tag for haddock, and second to improve the catching and handling technique so that needed tagging experiments could be carried out on the offshore banks.

The three experiments of 1938, 1939 and 1940 will be considered here. In all three years the haddock were tagged during the first part of June, in waters ranging from about 15 to 30 fathoms in depth, off Mount Desert Island, Maine. All of the haddock were caught by hook and line from a small one-man, line-trawl vessel employing commercial gear and fishing on a commercial scale. No fish were used for marking that had been hooked in the eyes, gills or throat, or through any sizable blood vessel.

Trial was made of three types of tags. The first type, a "bachelor button," designed by William C. Herrington on the basis of the results of live-car experiments, is attached to the opercle. Outside of the opercle is a concave aluminum disc, 15.7 millimeters in diameter, cupped 3 millimeters and stained with a red lacquer to increase visibility. This disc has a hollow shaft that goes through the opercle and is riveted by special pliers to an inner celluloid disc 15.5 millimeters in diameter. The riveting did not work very well under field condi-

tions. In the 1939 experiment so much difficulty in riveting was experienced that only a small number of fish was tagged and the poor early returns in this year suggest a heavy loss of the tags.

The second type of tag used was the modified Petersen disc, first used by Robert A. Nesbit on squeteague, consisting of two celluloid discs one-half inch in diameter, held together by a nickel pin. The pin was threaded through the center of the white disc and then pushed through the opercle from the inside. The red disc was then threaded on the projecting point of the pin. The surplus portion of the pin was cut off and the remainder twisted with a pair of long-nosed pliers.

The third type of tag was the internal anchor developed by the author during experiments on sockeye salmon. It consists of a strip of celluloid to the center of which is attached a fine chain bearing on the other end a colored celluloid "dangler." The strip was inserted

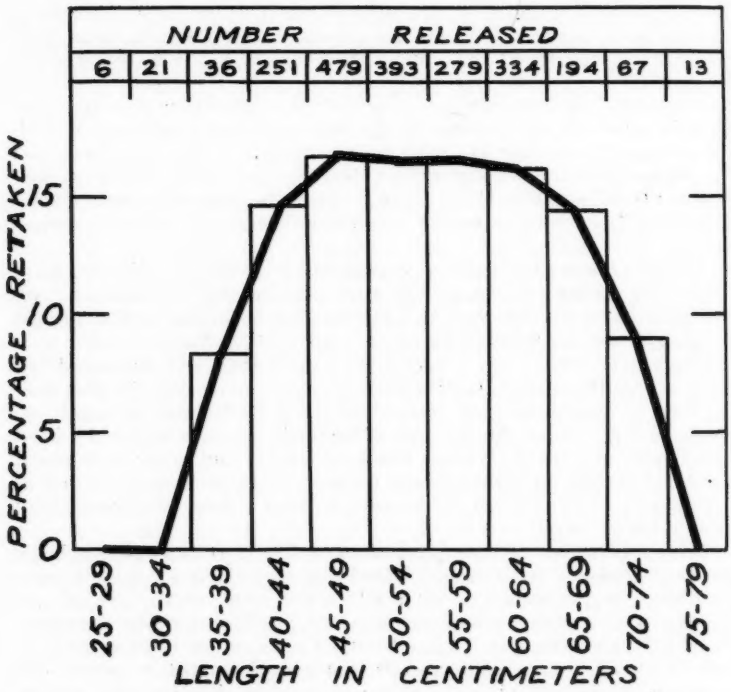

Figure 1.—The percentage of tags recovered from haddock in different size categories at the time of release.

through a cut into the body cavity, and the "dangler" hangs outside of the fish.

Different types of tags often have been tested by using different types on alternate days or even during different parts of the season. Such a system introduces an error that cannot easily be estimated, as any comparison between tags also includes the difference due to time of tagging. This source of error was eliminated by rotating the tags used, for instance, when three types were being tested, every third fish was marked with the same type.

In the three years 1938, 1939 and 1940, 2,073 haddock were marked and up to July 1941, 321 had been recaptured. The total return of 15.5 per cent, compared with 5.8 per cent in the best previous experiment, encourages the belief that the tagging of haddock will soon be established on an efficient basis.

Effect of Size on Returns

The effect on the recoveries of the size of the haddock when tagged is shown in Figure 1. The lower returns for the smaller haddock may be largely due to the rejection of these smaller sizes by the fishermen. The falling off in the returns from the larger fish may be due to a higher rate of mortality in these older fish.

Comparison of Number of Returns

In comparing the different types of tags, haddock between 40 and 69 centimeters in length when liberated, have been used, since, as shown in Figure 1, the percentage returns are quite uniform for fish of this size range. The resulting comparisons are shown in Table 1.

Since the disc tag was employed each year, it forms the basis for comparison. Note that in all three experiments the disc tag yielded the highest returns during the first one-half year. In both the 1938 and

Table 1.—Comparative recoveries of haddock marked with different types of tags
[Using fish only from 40 to 69 centimeters in length when released]

Date released	Type of tag	Number released	Specimens reported caught							
			First 6 months		Second 6 months		After 1 year[1]		Total	
			Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
June 1938.....	Anchor	93	5	5.4	3	3.2	4	4.3	12	12.9
Ditto	Button	247	16	6.5	8	3.2	8	3.2	32	13.0
Ditto	Disc	238	17	7.1	7	2.9	5	2.1	30	12.6
June 1939.....	Button	146	12	8.2	2	1.4	7	4.8	21	14.4
Ditto	Disc	333	38	11.4	16	4.8	14	4.2	69	20.7
June 1940.....	Anchor	416	38	9.1	12	2.9	....	....	51	12.3
Ditto	Disc	457	65	14.2	32	7.0	....	....	97	21.2

[1]Two years for 1938 experiment; 1 year for 1939 experiment.

1939 experiments it fell behind the other types after the lapse of 1 year. This higher initial recovery will be explained later.

In the 1938 experiment the button tag was almost the equal of the disc during the first 6 months, and led thereafter. In 1939, as explained above, we believe there was an initial loss of button tags due to mechanical defects that will need correction, but it nevertheless led the disc in recoveries after the first year.

The anchor tags have shown the lowest initial recovery due to the quick loss from the tag of the external dangler by which they can be easily observed without cleaning the fish. In the 1938 experiment the danglers were made of too thin a celluloid and broke away from the end of the chain. In 1939, the danglers were made of heavier material, but the additional weight broke the chains and the danglers thus were lost sooner than before. As soon as this mechanical difficulty is overcome, the external dangler will be retested as it appears to remain with the fish indefinitely.

Efficiency of Recovery

The differences in the percentage returns of the various tags, immediately raises the questions of whether it is due to differences in mortality of fish bearing certain types of tags, to the fish losing certain types of tags, or to variations in the ease with which certain tags are found. An attempt has been made to answer this question by showing the percentage of each tag recovered at different stages in the handling of the recaptured fish. (Table 2).

In explanation of Table 2 it should be pointed out that the sooner the tagged fish is "spotted" after capture the more the information available on the locality and date of recapture. Once a tag has gone beyond the wholesaler the data obtained is meager, and usually very little can be discovered about tags sent in by the consumer. Also it must be remembered that very likely only a portion of the tags that get past the wholesaler are actually found.

On the basis of Table 2 the anchor tag with the dangler attached holds the unique distinction of having none go beyond the wholesaler, but the numbers involved are too small to be significant. There is little to choose between the button and disc tag, but the anchor tags from which the dangler is missing showed very inferior recovery.

Visibility of Tags

Since there is some difference in the rate of recovery in relation to time, the method of recovery has been shown for tags returned during the first six months and those retaken subsequently (Table 3).

It should be noted that all types of tags show a much larger proportion passing beyond the wholesaler after the first 6 months at liberty. This loss in visibility may be ascribed to various causes. The

Table 2.—Stage of tag recovery by usual channels[1]

Type of tag	Found before leaving wholesaler								Found beyond wholesaler								Total returns
	Fisherman		Unloading		Wholesaler		Total of any		Retailer		Consumer		Both				
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage			
Disc	134	65.8	9	4.5	31	15.4	189	94.0	10	5.0	2	1.0	12	6.0			201
Button	35	66.0	5	9.4	8	15.1	51	96.2	2	3.8	....	....	2	3.8			53
Anchor with dangler	12	50.0	1	4.2	6	25.0	24	100.0	....	....	....	....	....	....			24
Anchor without dangler	22	53.6	2	4.9	7	17.1	31	75.6	6	14.6	4	9.8	10	24.4			41

[1]Recoveries were also made of one button tag found in lobster bait, and one disc tag with source unknown.

Table 3.—Effect of the time at liberty on the stage of tag recovery

Type of tag	Number caught first 6 months	Found beyond the wholesaler		Number caught after first 6 months	Found beyond the wholesaler	
		Number	Percentage		Number	Percentage
Disc	125	2	0.8	77	10	13.0
Button	27	0	....	26	2	7.7
Anchor without dangler	23	4	17.4	18	6	33.3

brilliant red celluloid of the disc tag gradually fades until after a year it may finally become a dirty brown. The button tag also decreases in visibility due to the gradual wearing off of the red lacquer.

Another cause of diminishing visibility is the tendency toward overgrowth of the tags by the opercular tissue. When disc and button tags are used it is quite usual for a layer of tissue to grow over the inside disc to protect the delicate gill filaments from constant chafing. On the outside of the operculum the situation is slightly different. Thus for the disc tag, since the outside disc has a non-rigid connection with the inside disc, if properly attached there is sufficient freedom to discourage overgrowth. However, if a disc tag is overgrown the resulting lump is so small that it attracts little attention. The advantage of free movement of the tag is also somewhat offset by the chances that the edge of the tag may become imbedded in the tissue, with the result that the disc tends to cut a large hole in the opercle and cause loss of the tag.

The button tag with its rigid shaft, is more easily overgrown by opercular tissue than the disc, but because of its deep concavity a large lump is formed on the side of the operculum that excites curiosity, and usually results in the discovery of the tag by someone who wants to see what is inside the lump.

When internal anchor tag has lost the outside dangler, the chain holds the tag against the inside wall of the body cavity at the place where it was first inserted and in a short while the tag becomes covered with a thin layer of transparent tissue. This circumstance may give the internal anchor tag an advantage over the belly tag which has no attachment. Experience with other species has shown that the plain belly tag often works out of the fish, either through the place of insertion or through some other spot in the body wall. This is now being tested in haddock by the use of plain belly tags.

From the above discussion it is clear that the actual mortality (natural mortality plus fishing mortality) of the tagged fish is much higher than is indicated by the actual number of recoveries. It illustrates the danger of coming to conclusions based on the use of a single type of tag that has not been adequately tested.

These experiments are being continued along the coast of Maine, and will be extended to the offshore fishing banks as soon as the renovation of the new research vessel, *Albatross III*, is completed.

Conclusions

These experiments have demonstrated that haddock can be tagged successfully when caught in water as deep as 30 fathoms by hook-and-line gear.

Of the three tags tested (bachelor button, disc, and internal anchor) the disc tag gave the highest initial returns, but gave poorer returns later. Owing to the protracted time over which recaptures are desired the button tag should prove more efficient than the disc if the mechanical defects are corrected. The anchor tag remains with the fish longer than the disc and possibly longer than the button, but must be mechanically improved before it can be employed in practice.

THE EFFECT OF POPULATION DENSITY OF LEGAL-SIZED TROUT UPON THE YIELD PER STANDARD FISHING EFFORT IN A CONTROLLED SECTION OF STREAM

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ABSTRACT

To determine how legal sized trout can be utilized most economically for the production of immediate fishing, the effect of different population densities of brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*) was evaluated in terms of the number taken by angling in a section of stream. Approximately one-quarter of a mile of Crystal Creek was blocked off by two weirs and the population density of trout controlled by periodic plantings. The yield per standard fishing effort was measured under different conditions in a series of fishing experiments. All catch data were reduced to a common level of numbers present by the analysis of covariance and comparisons between several classifications of fish were made. A highly significant difference was found between the catch of brook trout and brown trout with brook trout producing a much larger yield. The catch of brown trout was not significantly associated with the numbers present; evidently many factors in addition to population density operate in determining their catch. The catch of brook trout, however, was associated significantly with the population density, and this relationship was expressed by the equation:

$$Y = 0.0065\ X + 0.5183,$$

where $Y = \log\ (\text{catch} + 2)$,
and $X =$ number of brook trout present.

With a fishing pressure of 11.4 hours per day, it would be necessary to stock approximately 396 brook trout per mile of stream to provide for a catch of 1.0 fish per hour under the conditions of this experiment. Densities of 346 and 244 fish, respectively, would produce yields of 0.8 and 0.5 fish per hour.

It appears that brook trout are more desirable than are brown trout in the production of a maximum of fishing with the greatest economy. Their yield is much greater than that of brown trout and depends to a large extent upon the actual number stocked and not upon stream conditions as with brown trout.

INTRODUCTION

In recent years, fishery managers have resorted to plantings of legal-sized trout to provide fishing in many streams where conditions seem to indicate the need for this practice. It appears obvious that the yield can be increased in most situations by stocking numbers of legal-sized fish, and observations to this effect are numerous. However, little information is available concerning the efficiency of various methods of utilizing the planted legal fish in terms of the numbers actually taken by anglers. The cost of rearing yearling and 2-year-old fish is considerable and the demand for furnishing immediate fishing in many streams is increasing. Therefore, it appears important to determine how satisfactory fishing may be furnished most economically by using fish of catchable size and also how the highest catch may be

produced from the stocking of a certain number of legal-sized fish in certain situations.

Results of various investigations have shown an extremely low number of legal hatchery trout taken by angling in any fishing season from stock that had spent a winter period in the stream (Cobb, 1933; Nesbit and Kitson, 1937; Shetter and Hazzard, 1941; Smith, 1941). If these findings are accepted as evidence that a planting of legal-sized trout has a negligible effect upon fishing in seasons other than the one in which they were planted it is probable that not many survive for reproductive activities either. Therefore, the most efficient usage of such fish would be to take as large a percentage as possible soon after planting. On this basis it will be assumed that the most economical policy for the utilization of legal-sized trout calls for a high yield during a current fishing season, and all judgments of alternative methods of stocking will be made according to this criterion.

In order to develop a policy for the stocking of legal-sized trout that will produce the highest yield to anglers during the current fishing season it is necessary to determine how the catch is influenced by various numbers of trout planted, by the species of trout, and by different stocking methods. With this information at hand, it might be possible to set up a policy specifying the most economical number of fish to stock per mile of stream, the correct species, and method of planting to assure satisfactory fishing under a certain anticipated fishing pressure.

In an effort to solve these problems, an experiment was designed and carried out at Crystal Creek, New York States's experimental stream. The situation there made it possible to obtain information for the investigation of various phases of these problems. Materials were available for the construction of fish-tight weirs in the stream. Native brown trout were present in the stream in some numbers and hatchery brook trout and brown trout were available at the State hatcheries at Van Hornesville and Rome. It was possible to identify individual hatchery fish by the use of the method of jaw-tagging described by Shetter (1936). Four men were available for conducting the actual fishing, and materials and equipment were on hand for estimating population densities according to the electrical-shock method, (Haskell, 1940; Haskell and Zilliox, 1941).

Problems and Hypotheses

The general problem under consideration was to determine the effect of different densities of hatchery brook trout and brown trout and native brown trout in a controlled section of Crystal Creek upon the catch per standard fishing effort under different conditions. Undoubtedly, there are many factors that might influence the yield in this situation. Under the conditions of the experiment, the effects of several factors which were deemed important from preliminary observation were tested.

1. It was important to know, first of all, which of the two species of trout considered would produce the greater yield. Thus the first problem became: Is there a significant difference in the yield of hatchery brook trout and hatchery brown trout per standard fishing effort in a controlled section of Crystal Creek?

2. The possibility that recently-planted fish will produce a different yield by reason of their being more easily taken than those which have been in the stream for several weeks suggested the second problem: Are there significant differences in the yields of brook trout that have been in the stream for 2 weeks (15-19 days), 1 week (8-12 days), and less than 1 week (1-4 days)?

3. There is a possibility that trout that have survived a winter period and that may have become more acclimated to the stream will contribute differently to the catch than will fish planted during the current fishing season. For convenience, *native* trout are defined as all legal-sized brown trout that have been in the stream one winter period or longer. *Hatchery* trout are defined as those which have been planted during the current fishing season. Thus the third problem became: Under the conditions of this experiment, is the yield of wild and hatchery brown trout significantly different?

4. It appears to be of importance to determine if the catch can be influenced by plantings of various numbers of hatchery trout. If the yield varies directly as the number present in a section of stream, it would be possible to compute the number of fish that should be stocked per mile of stream to produce "fishing satisfaction" for the average angler. It would also be possible to predict the yield that would be produced when a certain number of legal fish are planted. The fourth problem, therefore, was: Does the number of legal-sized hatchery fish (either brook trout or brown trout) in a controlled section of Crystal Creek influence the yield per standard fishing effort. In other words, is there a significant difference in the yield with different numbers of either species present?

The solution to these problems can be stated exactly by means of the null hypothesis (Fisher, 1937), which may be worded as follows: If populations of fish yields are normally distributed, then experimentally determined yield statistics (mean and variance) will follow the normal law. This hypothesis is to be tested in each of the four problems. If, contrary to this hypothesis, in any particular problem the statistics found prove *not* to follow the normal law, then it may be inferred that a significant difference exists. The implications of this difference in relation to the different classes involved may then be explored.

Design of the Experiment

It appears likely that the above hypothesis can be tested by experiments utilizing standard experimental designs and the analysis of covariance for the reduction of the data so obtained. If the catch per

standard fishing effort is measured under conditions conforming to these designs in situations where hatchery brown trout and brook trout and native brown trout are present in different numbers and for different periods of time, then data can be obtained which can be reduced by the analysis of covariance (Fisher, 1937) to provide tests of the various parts of the null-hypothesis. If the yields are adjusted to to common level of numbers present, then they can be compared. If the factors mentioned above are important, then they will produce differences in the yield that can be recognized as significant by Snedecor's *F*-test.

The materials and methods that were used in estimating the catch under different conditions in a section of Crystal Creek are discussed and defined in the following paragraphs.

A section of stream 1,247 feet long with an average width of 27 feet was blocked off from the rest of the stream by the construction of a weir at each end of the section. It appeared impossible for any legal-sized fish either to enter or leave the area. Thus it was possible to control the population density by adding or removing given numbers of fish. The enclosed section was designated as the *controlled section.*

In this experiment legal-sized trout are all trout 7 inches long or longer. The hatchery trout planted were 8 to 12 inches long (total length).

The *population density* has been defined as the number of legal-sized trout in the controlled section at any time. It was varied by periodic plantings as the experiment progressed. Approximately 50 brook trout and 50 brown trout were planted each week for 3 weeks. Records were kept of all fish removed by fishing and by other means. Thus an estimate of the density was available at all times. At the conclusion of the fishing, an estimate of the population of wild trout was made with the "electric shocker" (Haskell, 1940; Haskell and Zilliox, 1941).

The *yield* or *catch per standard fishing effort* is the number of legal trout taken in a single fishing day by the four anglers who conducted the experiment. The fishing day was an average of 11.4 hours for all anglers combined, or an average of 2.85 hours per day for each of four anglers. The fishing day is therefore a measure of the *fishing pressure* under which the catches were made.

Fishing satisfaction is defined arbitrarily as an average catch of 1.0 legal trout per fishing hour.

Each *fishing week,* of which there were three, was composed of the fishing efforts of 4 consecutive days. Each fishing day, 6 a.m. to 10 p.m. was divided into four 4-hour periods and fishing occurred in each period of every day throughout any particular fishing week. Each angler fished once a day in the period assigned to him by a method of stratified random sampling that followed a Latin-square arrangement. The assignments had one restriction, in that every 4 days, each of the four anglers would have fished once during each of the periods.

The *method of fishing* was restricted to the use of a rod, line and artificial fly. The entire test section of 1,247 feet was covered at least once by an angler in his 4-hour period and as many more times as his speed of fishing permitted.

On each of three occasions approximately 50 brown trout and 50 brook trout of legal size were stocked in the controlled area. The fish were tagged with jaw tags, weighed, measured and distributed evenly throughout the section by planting at 13 stations, located every 100 feet along the stream. At each planting of 100 fish, approximately 4 individuals of each species were planted opposite each of the stations.

The Data

The data that were required to estimate the yield per standard fishing effort and to test the null hypothesis consisted of the date and period of day when fishing occurred for each angler, the number of hours fished, the number of the various kinds of fish taken, and the tag number of marked fish. The numbers of each class of fish in the stream during each fishing day were obtained by subtracting the number taken each day from the corresponding total number planted. At the conclusion of the fishing operations there were supposedly 174 hatchery fish remaining in the section. Estimation (by the method of electrical shocking) of the population present at this time indicated that approximately that number actually were in the controlled section. Prior inquiry has shown this method of recapture to recover from 80 to 90 per cent of this size fish actually in a section of this type. A recovery of 141 is about 81 per cent of the population theoretically present. This recovery seems to be within the limits of expectation for the method. The estimates of the numbers of fish present at any fishing day appear to be reasonable.

A total of 29 native brown trout were also recovered by means of the electrical shocker. If the native and hatchery fish were taken at the same rate, then a recovery of about 80 per cent is indicated for native fish also. Thus the best estimate of the native trout population present at the close of fishing operations would be 36 fish. The total number present on any fishing day was thus easily computed from this figure.

Tests of Significance

Examination of the original data reveals variations in the yields of the three types of fish under consideration. Under conditions of equal fishing pressure in the complete experiment, 46 hatchery brown trout, 84 hatchery brook trout, and 4 native brown trout were taken. Other variations are less noticeable. The significance of all variations, however, is obscured by the presence of different numbers of the several types in the stream at the time of fishing. To test the significance of any of the differences it is first necessary to adjust the catches to a standard number of fish present in the stream. This adjustment was

Table 1.—The daily number of fish present (X) and the catch per standard fishing effort (Y) for wild and hatchery brown trout and hatchery brook trout in each of three fishing weeks

Week	Day	Hours	Native brown trout		First planting				Second planting				Third planting				Total plantings			
					Brook trout		Brown trout		Brook trout		Brown trout		Brook trout		Brown trout		Brook trout		Brown trout	
			X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	Tues.	13.00	40	1	48	6	57	10	....	....	....	....	....	....	....	....	48	6	57	10
	Wed.	11.50	39	0	42	7	47	2	....	....	....	....	....	....	....	....	42	7	47	2
	Thurs.	13.25	39	0	35	4	45	1	....	....	....	....	....	....	....	....	35	4	45	1
	Fri.	10.75	39	0	31	3	44	1	....	....	....	....	....	....	....	....	31	3	44	1
2	Tues.	9.75	39	0	28	1	43	1	50	12	52	4	....	....	....	....	78	13	95	5
	Wed.	10.00	39	2	27	2	42	0	38	5	46	0	....	....	....	....	65	7	90	0
	Thurs.	10.25	37	0	25	3	42	1	33	2	46	0	....	....	....	....	58	5	90	1
	Fri.	11.75	37	0	22	2	41	4	31	1	48	1	....	....	....	....	53	3	89	5
3	Tues.	12.50	37	0	20	2	37	3	30	3	47	2	52	12	53	11	102	17	137	16
	Wed.	10.25	37	0	18	3	34	1	27	3	45	0	40	4	42	2	85	10	121	3
	Thurs.	10.25	37	1	15	1	33	0	24	0	45	0	36	3	40	0	75	4	118	0
	Fri.	12.50	36	0	14	0	33	0	24	0	45	1	33	6	40	1	71	6	118	2
Totals		136.75	4		34		24		26		8		25		14		85		46	

Table 2.—The reduction of the data for the analysis of covariance and test of significance between yields of hatchery brook trout and brown trout

Source of variation	Degrees of freedom	Sum of squares and products			Errors of estimate		
		Sx	*Sxy*	*Sy*	Sum of squares	Degrees of f eedom	Mean squar·
Total	23	22,785.8	15.600	1.7325	1.7281	22	.....
Species	1	4,482.6	—41.956	0.3927	.....	. .	
Error	22	18,303.2	57.556	1.3398	1.15888	21	0.0552
Fo· test of significance.....					0.5630	1	0.5630

$$F = \frac{0.5630}{0.0552} = 10.20;\ n_1 = 1;\ n_2 = 21.$$

accomplished for all four problems by the analysis of covariance (Snedecor, 1938), utilizing the actual number of fish present and the logarithms of the daily catch plus two.

Prior inquiry indicated that this transformation normalized the data. Curvilinear regression and correlation between mean and variance were eliminated by this procedure.

Problem 1.—The reduced data for the test of significance of the difference between the yields of hatchery brook trout and brown trout are shown in Table 2. The data used in making the test are the complete records of hatchery brook trout and brown trout, to be found in Table 1 in the column titled, "Total plantings." An F value of 10.20 with 1 and 21 degrees of freedom indicates that even after the catches were adjusted to a common level of numbers they still differed significantly. More brook trout than brown trout were taken.

Problem 2a.—The reduced data used in the comparison of the catches of different groups of brook trout that had been in the streams varying periods of time are presented in Table 3. They consist of the records of the hatchery brook trout that had been in the stream for 2 weeks (15-19 days), 1 week (8-12 days) and less than 1 week (1-4 days). An F value of 2.0 with 2 and 8 degrees of freedom is not significant. Thus there was no difference in the catch of brook trout between any of the periods.

Problem 2b.—The reduced data to compare the catches of hatchery brown trout that had been in the stream varying periods of time are

Table 3.—The reduction of the data for the analysis of covariance and test of significance between yields of brook trout that has been in the stream for 2 weeks (15-19 days), 1 week (8-12 days), and 0 weeks (1-4 days)

Source of variation	Degrees of freedom	Sum of squares and products			Errors of estimate		
		Sx	*Sxy*	*Sy*	Sum of squares	Degrees of freedom	Mean squa·e
Total	11	1374.25	25 02	0.7353	0.2798	10	.....
Weeks	2	1118.00	18.24	0.3708	.....	....	.....
Error	9	256.25	6.78	0.3645	0.1851	8	0.02314
For test of significance.....					0.0947	2	0.04735

$$F = \frac{0.04735}{0.02314} = 2.0;\ n_1 = 2;\ n_2 = 8.$$

presented in Table 4. They are based on records similar to those given above for the brook trout. An F value of 17.86 with 2 and 8 degrees of freedom is highly significant, indicating a marked difference in the catches for various periods in the stream. The adjusted mean catches for 2 weeks, 1 week and 0 weeks are 0.8538, 0.1639, and 0.4702. These are the catches to be expected if equal numbers of each "week class" were present. The catch of the 2-week priod is significantly higher than either of the other two periods, indicating that some factor other than density was operating that affected significantly the catch of brown trout.

Table 4.—The reduction of the data for the analysis of covariance and test of significance between yields of brown trout that has been in the stream for 2 weeks (15-19 days), 1 week (8-12 days) and 0 weeks (1-4 days)

Source of variation	Degrees of freedom	Sum of squares and products			Errors of estimate		
		Sx	*Sxy*	*Sy*	Sum of squares	Degrees of freedom	Mean square
Total	11	424.0	9.11	0.6331	0.4374	10	.....
Weeks	2	293.5	1.40	0.0975	.....	....	.....
Error	9	130.5	7.71	0 5356	0.0801	8	0.0100
For test of significance					0.3573	2	0.1786

$$F = \frac{0.1786}{0.0100} = 17.86; \; n_1 = 2; \; n_2 = 8.$$

Problem 3.—The reduced data to test the significance of the difference between wild and hatchery brown trout (Table 5) consist of the complete catch records of brown trout under columns headed "Total plantings" and "Native brown trout" in Table 1. An F value of 2.7 with 1 and 21 degrees of freedom is not significant. Thus, after the numbers present have been equalized, there is no difference in the numbers taken.

Problem 4a.—To determine whether significant differences in the yield of legal-sized trout are associated with actual numbers of fish in the stream, a correlation coefficient, r, was estimated for each of the three classes of trout—hatchery brook trout, hatchery brown trout, and native brown trout—between the actual numbers present and the logarithm of the daily catch plus 2. This transformation may be ex-

Table 5.—The reduction of the data for the analysis of covariance and test of significance between yields of native and hatchery brown trout

Source of variation	Degrees of freedom	Errors of estimate			Sum of squares and products		
		Sx	*Sxy*	*Sy*	Sum of squares	Degrees of freedom	Mean square
Total	23	29,054	120.490	1.6686	1.1689	22	.....
Fish	1	15.760	95.325	0.5766	.....	....	.....
Error	22	13.294	25.165	1.0920	1.0444	21	0.0497
For test of significance					0.1245	1	0.1245

$$F = \frac{0.1245}{0.0497} = 2.5; \; n_1 = 1; \; n_2 = 21.$$

pressed as log (catch + 2). The values of r, were 0.217 and 0.329 for hatchery brown trout and native brown respectively. These values, with 10 degrees of freedom are not significant. The catches of both types of brown trout, therefore, were not found to be associated with the numbers present. Possibly many other factors that affect the catch of brown trout have obscured this relationship. A more extensive experiment would be necessary to gain information concerning the catch of brown trout as it appears to be extremely variable.

Problem 4b.—A value of $r = 0.766$ for brook trout, however, is highly significant, and indicates that the catch of hatchery brook trout is influenced strongly by the numbers in the stream. The relationship between the number of brook trout present in the test section of Crystal Creek and the number caught per standard fishing effort is expressed by the following equations:

$$Y = 0.0065\,X + 0.5183,$$

where X = number of brook trout present.

and $Y = \log (\text{catch} + 2)$,

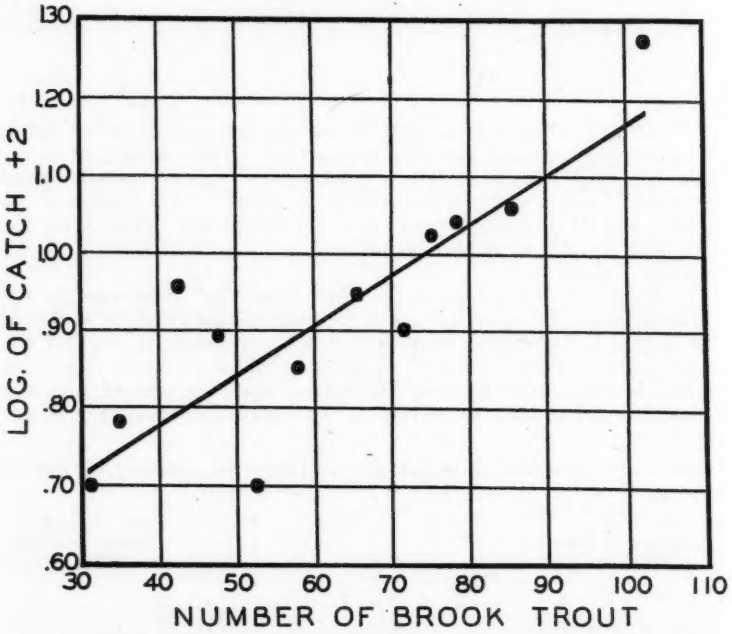

Figure 1.—The relationship between the number of brook trout present in the test section of Crystal Creek and the number taken per standard fishing effort of 11.4 hours per day

Table 6.—The calculated numbers of legal-sized brook trout per mile of stream required to produce certain yields in terms of the catch per fisherman-hour and the catch per day by four anglers

Number of fish per mile of stream	Catch per hour	Catch per day by four anglers
131.2	0.29	3.25
148.1	0.31	3.57
177 8	0.37	4.18
203.2	0.42	4.77
224.4	0.46	5.29
245.6	0.51	5.86
275.2	0.59	6.73
300.6	0.66	7.55
317.6	0.71	8.13
330.3	0.77	8 60
359.9	0.86	9.78
431.9	1.16	13.18

This relationship is shown in Figure 1. The relationship between the number of fish per mile of stream and the catch per hour of fishing is shown in Table 6 and Figure 2. It can be seen from Figure 2 that to produce "satisfactory" fishing, which has been defined arbitrarily as a catch of 1.0 legal trout per fishing-hour by the average angler, it would appear necessary to have a stock of approximately 396 fish present per mile of stream. About 346 fish per mile would produce a yield of 0.8 fish per hour and 244 fish per mile would provide a yield of 0.5 fish per hour.

It is important to know how long a given planting will produce

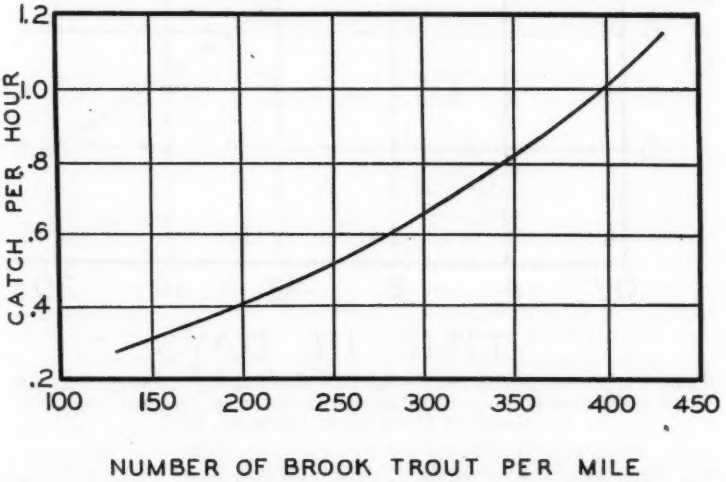

Figure 2.—The relationship between the number of brook trout in a mile of stream and the catch per hour of fishing

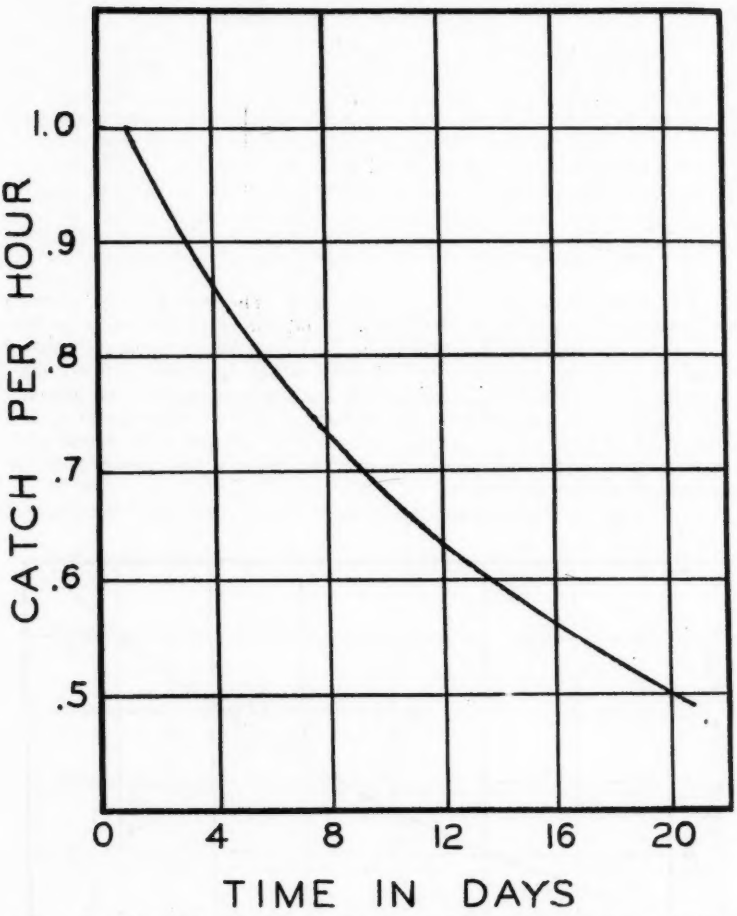

Figure 3.—The relationship between the time in fishing days following a planting of 396 brook trout in a mile of stream and the catch per fisherman hour, with a pressure of 11.4 hours of fishing per day

good fishing with a certain fishing pressure. A stocking of 396 legal-sized brook trout per mile of stream with an angling pressure of 11.4 hours per day might furnish 21 days of fishing before the average catch would fall below 1.0 fish per angler per 2-hour period of fishing. The relationship between time in fishing days following a planting of 396 fish per mile of stream and the catch per fisherman hour with a pressure of 11.4 hours a day is shown in Figure 3.

Conclusions

The following assertions seem warranted with reference to the null hypothesis as outlined in the second section of this paper:

1. In the first problem the null hypothesis was disproved. The catch of hatchery brook trout was significantly greater than the catch of hatchery brown trout.

2a. In the first part of the second problem the null hypothesis was not disproved. Brook trout that had been in the stream different periods of time were taken equally well.

2b. In the second part of the second problem the null hypothesis was disproved. Brown trout that had been in the stream for a period of 2 weeks were more readily taken than those that had been in the stream either 1 week or 0 weeks.

3. In the third problem the null hypothesis was not disproved. There was no difference in the yield of native and hatchery brown trout.

4. The null hypothesis was not disproved in the fourth problem in respect to brown trout. There were no differences in the catch of brown trout that were associated with population density. With respect to brook trout, however, the null hypothesis was disproved. The yield of brook trout was associated significantly with the density of the population in the stream.

From these results, it appears that brook trout are more desirable than brown trout for the production of fishing returns. The yield of brown trout was much smaller than was the yield of brook trout and was also variable and unpredictable. A stocking of a large number of brown trout did not necessarily assure a large yield, as many factors in addition to the density of the population in the stream evidently affected the numbers caught.

The catch of brook trout was much greater than the catch of brown trout. This fact alone should make brook trout more economical for the production of fishing "satisfaction." The catch depended largely upon the actual number stocked and varied little with stream condition. Thus, with a certain fishing pressure, it is possible first to determine how many fish need be stocked to furnish satisfactory fishing and second, to predict the return to anglers following a given planting. In view of these characteristics it appears that brook trout are more satisfactory than brown trout in the production of a maximum

of fishing with the greatest economy under the conditions of this experiment.

ACKNOWLEDGEMENT

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FISH MANAGEMENT PROBLEMS OF HIGH WESTERN LAKES WITH RETURNS FROM MARKED TROUT PLANTED IN UPPER ANGORA LAKE CALIFORNIA[1]

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ABSTRACT

Upper Angora Lake in the high Sierra Mountains was selected for an experimental study conducted from 1934 to 1936, inclusive. It is a small 5-acre lake lying at an elevation of 7,800 feet, 7 miles south of Lake Tahoe. General ecological conditions and management problems of such high lakes are discussed. Low water temperatures over most of the year limit both growth of fish and production of aquatic foods. The standing crop of bottom foods averaged 49 pounds (wet weight) per acre. Dominant aquatic foods were midge larvae, bristle worms (oligochaetes) and scuds (*Hyalella*). Stomach examinations of trout indicated that dominant foods eaten were midge larvae and pupae. Aquatic organisms formed over 66 per cent by number of foods eaten.

Two lots of marked eastern brook trout were planted, one of 5,028 averaging about 2 inches in length, and another of 2,080 averaging 5½ inches in length. The small fish were planted in September 1933 and the larger in June 1935. Both lots were marked by removal of fins. The lake outlet was screened to prevent fish from leaving the lake.

A creel census was taken throughout the angling seasons of 1934, 1935 and 1936. Only weight, species, date of capture, and the presence or absence of marks were recorded. No record was kept of the length of time each angler fished or of anglers who failed to catch fish.

Catches of both marked and unmarked fish totaled 89 trout in 1934, 809 in 1935, and 211 in 1936. Eastern brook trout were dominant in the catches. A few rainbow and brown trout were taken each year.

Over the 3-year period covered, only 4.3 per cent of the 5,080 2-inch eastern brook trout, and 25.6 per cent of the 5½-inch fish, were reported caught. Judging from the results of work presented in this paper and the results of the work of other investigators cited, losses of trout planted are extremely heavy regardless of the size of fish planted.

Better survival of small 2-inch trout was obtained after three winters in the lake than for 5½-inch fish after only one winter in the lake. Marked fish of both plantings formed 77 per cent and 58 per cent, respectively, of fish captured and retained in 1935 and 1936. No marked fish were reported in 1934. The planting of small eastern brook trout made in the fall of 1933 contributed most fish to anglers the second year after stocking. The planting of larger trout contributed most in the same season in which they were stocked. The small marked trout grew at a rate of over 2.5 inches per year for the 3-year period covered by the creel census, and the larger grew at a rate of 1.7 inches per year.

[1]The writers are indebted to the California Division of Fish and Game, Mr. H. J. Rayner, Mr. Leo Erkkila and Mr. F. K. Cramer for much aid in this work. Thanks are also rendered to Mr. and Mrs. A. W. Hildinger, who recorded anglers' catches on Angora Lake.

Production in pounds per acre was 15.8 in 1934, 21.2 in 1935, and 17.0 in 1936. Eastern brook trout formed 28 per cent by weight of all trout landed in 1934, 93 per cent in 1935, and 48 per cent in 1936.

Age determinations from scale studies indicated that the majority of eastern brook trout caught were in their third year, and the presence of incoming young in their first and second years gave evidence of successful natural propagation in the lake. No rainbow trout less than 3 years old or brown trout less than 5 years of age, were present in the samples studied.

Fifteen brown trout that averaged 2.18 pounds each and weighed up to 7 pounds were reported caught in 1936. Predation by a few large brown trout is suggested as one cause of the low survival of planted trout and the removal of such fish by selective gill-netting operations is presented as a possible management measure in lakes where destruction of entire populations by poisons or other means is not desired.

Introduction

Many anglers have witnessed the planting of trout in high mountain lakes in the western United States. Many persons also have seen freshly-planted small fingerlings being eaten by larger fish already present and it is not uncommon to hear remarks to the effect that but few of those planted ever survive. While such observations do not produce accurate figures on the survival of a restocking effort, they are often confirmed later by angling which fails to produce the good fishing anticipated.

Management problems in intensively fished lakes largely resolve themselves into the necessity for making decisions as to the best size, species, and numbers of trout to plant; frequency of plantings; and whether or not improvements should be attempted or regulations changed. If any given species fails to produce, the remedy usually is to try another species or plant more of the same species. Overstocking is more of an evil than understocking. It usually makes a bad condition worse. The study of Upper Angora Lake was an attempt to obtain solutions to some of these problems. It was selected for study because in addition to being a typical small, heavily fished, high Sierra lake, it offered, by reason of its location, easy control for making a complete creel census of fish taken each season.

Method

The data were collected during the years 1934 to 1936, inclusive. Two lots of marked eastern brook trout (*Salvelinus fontinalis*) were planted, one of small fish in the fall of 1933 and one of large fish in June 1935. From a creel census, survival and growth were determined over the 3-year period.

To prevent the brook trout from leaving the lake, the outlet was screened immediately before planting any marked trout. During the maximum run-off period in June 1934, the screen became clogged and water passed over it for several hours on several different days. The outlet usually dries up early in the summer after the inflow has ceased.

Fall storms usually start it flowing again in November or December depending upon seasonal conditions, but its maximum discharge is in the spring during late May and June and during such periods it was necessary to keep a close watch at the screen to keep water flowing through it. It is believed that emigration of fish from the lake was negligible since only one marked brook trout was captured in Lower Angora Lake.

It is possible to drive within half a mile of the lake. There is only one resort on the lake, which is strategically located at the head of the only trail so that catch records were easily collected. On the trail to the lake and along the shoreline, signs were posted requesting the cooperation of anglers in reporting their catches. It is estimated that the catch records are 95 per cent complete.

Only weight, species, date of capture, and presence or absence of marks were recorded. The length of each fish was not recorded. The length frequency distribution given in Figure 2 is based upon length measurements of random catches and upon fish captured in gill-nets. To reduce the labor and cost of securing data, no record was kept of the length of time each angler fished or of anglers who failed to catch fish. Hence no data are presented giving the catches in terms of catch per unit of effort.

The principal method of fishing is by fly- or bait-casting from the shore. A few boats are available for rent at the resort. Many anglers use salmon eggs or worms and still-fish from either the bank or boats.

Physical Data

Upper Angora Lake lies in a granitic basin on the north side of Echo Peak, at an elevation of 7,800 feet, and at a distance of about 7 miles from the southern end of Lake Tahoe. The surface area of the lake is about 5 acres. Its shape is roughly circular (Figure 1). The greatest depth of 50 feet was found near its southwest side which is bounded by a cliff. It averages about 25 feet deep in the center, while about one-fourth of the lake on the north side averages less than 10 feet deep. The lake is fed by melting snow from several very small streams that cascade down the almost vertical cliffs above the south shore. These are usually dry by midsummer. After the snow has melted, the surface level drops about 2 feet by evaporation each summer. The single outlet, located on the northeast side of the lake, flows down into Lower Angora Lake, one-fourth mile below.

There are said to be more than 8,000 lakes over 5 acres in surface area between the northern and southern limits of the Sierra Nevada Mountains in California. Most of them lie in glacial cirques just below the crest of the main divide. This setting of bare rock, with occasional stunted lodgepole pines, gives the general impression of extreme barrenness. Most of the inlets, like those in Upper Angora Lake, enter over steep slopes or cliffs which renders them inaccessible to spawning fish.

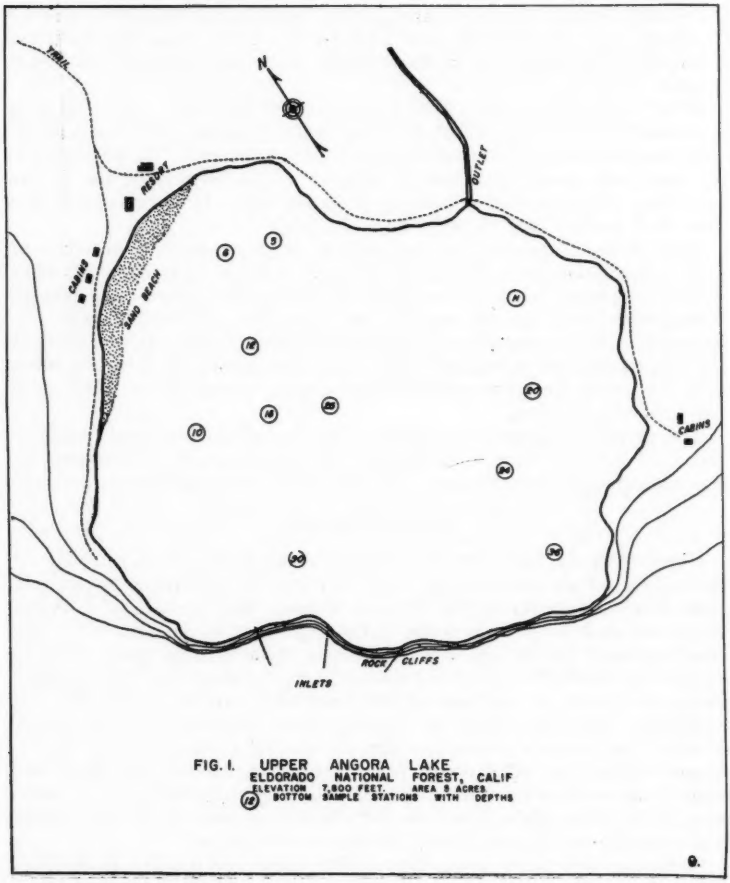

FIG. 1. UPPER ANGORA LAKE
ELDORADO NATIONAL FOREST, CALIF
ELEVATION 7,800 FEET. AREA 9 ACRES
(12) BOTTOM SAMPLE STATIONS WITH DEPTHS

Sierra lakes often occur in chains, one below the other, with the outlet of the upper becoming the inlet of the one below. In such cases the lower lakes usually have better spawning inlets than the uppermost lakes, because their inlets are more permanent and generally more accessible to fish. Upper Angora Lake, as the name implies, lies at the head of its drainage basin.

The great majority of high Sierra lakes can be reached only by trail, and the angling intensity is therefore light. A few of them lying near roads are subject to extremely heavy angling, particularly during the summer vacation season from the middle of June to the middle of September. Most high Sierra lakes were originally barren of fish life because of impassable falls that prevented migration into them, but many of them have been stocked during the past few decades. Suitable natural spawning facilities are often lacking which makes periodic restocking necessary.

Water Temperatures and Climatic Conditions

Only scattered water temperature records were taken in Upper Angora Lake, and these indicate definite thermal stratification of the water. For instance, on June 22, 1933, when the air was 64.0° F., the surface was 58.5° F., while a temperature of 43° F. was recorded at the bottom of the lake in 50 feet of water. On September 20, 1933, surface temperatures were 60° F. in shallow water at the side of the lake and 57° F. in the center of the lake. In midsummer, maximum surface water temperatures approach 70° F. but for most of the growing season remain in the sixties or below.

Study of meteorological data taken at the nearest station of the U. S. Weather Bureau at Tahoe City (located on Lake Tahoe about 22 miles south of Upper Angora Lake and at an elevation of 6,230 feet) indicates that between 1922 and 1939, inclusive, the number of days between killing frosts varied from a low of 40 days to a maximum of 104 days, with an average of 77 days.

Over a 22-year period from 1909 to 1931, inclusive, snowfall averaged 213.9 inches annually or almost 18 feet at the Tahoe station. Annual precipitation averaged 29.41 inches over the same period. The mean annual air temperature at the Tahoe station from a 30-year record through 1939 was 44.3° F. Below-zero air temperatures are infrequent. The lowest recorded was —15° F., and the warmest 93° F.

As noted above, Upper Angora Lake lies at an elevation of about 7,800 feet, or some 1,570 feet higher than, and 40 miles south of, Tahoe City, where the U. S. Weather Bureau station is located. Heavier annual precipitation and snowfall, lower temperatures, and a shorter growing season could safely be expected at Angora Lake as compared to conditions at the Tahoe station. Another factor tending to reduce the growing period at Angora Lake is its location. It lies in a deep pocket in a glacial cirque on the northeast side of Echo Peak, approximately 800 feet below a steep-sided ridge which intercepts the

sun's rays long before it has actually set. The length of the growing season at Angora Lake would be considerably less than at Lake Tahoe. In terms of lake water temperatures, the period during which good growth is possible would certainly not extend much over 130 days.

Heavy snow and ice usually blanket such high lakes. Often, depending upon temperatures and snow or rain, several layers of snow and ice, or water and ice, form. An early freeze followed by a heavy snowfall may, by virtue of its weight, push the ice below water, wetting the snow on top to form a layer of slush. This slush often freezes solid and may in turn be covered by additional snow which pushes the lower layers still deeper.

A clearly marked ice zone is evident in the shallow parts of Angora Lake and most other high Sierra lakes. Pressure of the ice, and its consequent erosive action on rocks in shallow water areas near the shoreline, leaves a distinct, easily recognizable, light-colored band or zone which apparently is created by the grinding action of the ice which wears away the darker weathered rock surfaces giving a lighter tone to the rocks.

With the advent of fall storms, the complete exclusion of light by successive layers of both snow and ice must quickly stop all photosynthetic action by phytoplankton and also arrest the consequent oxygen production. Very little work has been done to date on winter conditions in high mountain lakes, but it may be assumed that only the scarcity of oxygen-consuming materials prevents complete oxygen depletion and so-called "winter-kill" of trout in such waters. Once light is excluded, the oxygen supply must be sufficient to support both animal and plant life until spring when the lake surface opens again. Winter killing of trout is frequently reported from small, shallow mountain lakes in which case, the cause must be oxygen depletion coupled with an increase of carbon dioxide and gases such as methane and hydrogen sulphide that are by-products of decomposition. Angora Lake, while only 5 acres in surface area, nevertheless has a maximum depth of 50 feet, and only a comparatively small area of shallow water less than 10 feet in depth. The deeper, sub-littoral areas must be essential to survival of trout in lakes like Angora where severe winter conditions prevail.

Fishes Present

Fishes reported present in the lake at the time the study was commenced were eastern brook trout (*Salvelinus fontinalis*) brown or Loch Leven trout (*Salmo trutta*), rainbow trout (*Salmo gairdnerii*), and cut-throat trout (*Salmo henshawi*), lake chubs (*Siphateles obesus*), and the bluegill sunfish (*Helioperca macrochira*). The last two were doubtless the result of accidental introduction by bait fishermen. No identifiable cutthroat trout were taken in the course of the investigation.

Planting records of the California Fish and Game Commission indicate that more eastern brook were planted in Angora Lake than other

species of trout, though good numbers of rainbow and cutthroat trout were intermittently planted between 1926 and 1929. The first brown trout were planted in 1922 when 8,000 were allotted to the resort owner on the lake. Eastern brook trout were first planted in 1930 which was the last year that rainbow trout were planted. The number stocked varied from 10,000 to 30,000. The earlier planting records are not accurate.

Bottom Foods

Bottom materials, judging by Ekman dredge samples taken in 1933 and in 1936, consist generally of plant detritus and silt below a depth of 25 feet. Growing plants were found at 24 feet and also a sparse growth of *Nitella* and quillwort (*Isoetes*) at 15 feet. Scattered patches of quillwort appeared in shallow water, but such areas consisted mostly of granitic sand and gravel sparsely overlaid by plant detritus, principally from nearby coniferous trees.

Eleven Ekman dredge samples were taken, three in June 1933, and eight in October 1936 (Table 1). Midge larvae were the most abundant organisms, comprising 91 per cent by number of all organisms taken. No midge pupae were taken. Oligochaetes, next in order of abundance, comprised only 6.3 per cent of the total. Other organisms taken include the scud, *Hyalella azteca*, and small clams (*Pisidium*). Trout stomach examinations also revealed the presence of alder-fly larvae (*Sialis*), caddisfly larvae, and water mites. The wet weight of foods from the eight Ekman samples taken in October 1936, indicate a bottom faunal population or "standing crop" amounting to an average number of 155 organisms per square foot (1,667 per square meter), or an average wet weight of 49 pounds per acre. Since these averages are based on samples taken in the more productive, shallower areas, bottom production for the entire lake might be somewhat lower than the averages given.

These amounts of food are in close agreement with amounts reported

Table 1.—Details of bottom samples from Upper Angora Lake taken with an Ekman dredge

No.	Date	Depth (feet)	Wet weight of organisms[1]	Type of bottom	Bottom Organisms				
					Midge larvae	Bristle worms	Scuds	Clams	Total
1	June 22, 1933....	50	.....[2]	Plant detritus, silt	2	1	0	0	3
2	Ditto	15	.....[2]	*Nitella*, sedges on sand	30	1	0	1	32
3	Ditto	5	.....[2]	Detritus, sand, gravel	76	2	0	3	81
4	Oct. 15, 1936	25	0.478	Plant detritus, silt	64	0	0	0	64
5	Oct. 18, 1936	10	0.053	Plant detritus, sand	53	4	3	0	60
6	Ditto	12	0.035	Ditto	39	6	0	1	46
7	Ditto	11	0.010	Sand, gravel	7	1	1	0	9
8	Oct. 20, 1936	20	0.267	Plant detritus, silt	42	2	0	0	44
9	Ditto	24	0.042	Plant beds, detritus	21	8	0	0	29
10	Ditto	36	0.000	Plant detritus, silt	0	0	0	0	0
11	Ditto	6	0.137	Detritus, sand, gravel	53	2	0	3	58

[1]Results expressed in grams per ¼ square foot. [2]Not secured.

from high lakes in the Sierra National Forest by Needham and Hanson (1935). They reported an average wet weight of 57 pounds per acre or 122 animals per square foot (30.4 per Ekman dredge sample of ¼ square foot) from 23 natural lakes lying at high elevations.

Foods Eaten by Trout in Upper Angora Lake

Stomach examinations were made of 21 eastern brook trout, 9 rainbow trout, and 5 brown trout caught in Angora Lake in June, July, August, and October of 1933, 1934, and 1936. Their average total length was 11½ inches and they varied from 2.2 inches to 24.4 inches. The average total length by species was: Eastern brook trout, 9.3 inches; rainbow trout, 12.8 inches; and brown trout, 18.1 inches.

Out of a total of 5,003 food items consumed, approximately 66 per cent were aquatic in origin. Only 33 per cent were land insects that had been blown or had fallen into the water. Dominant aquatic food elements were midge larvae or pupae, and water mites. Midges made up over 76 per cent, and mites over 19 per cent, of aquatic foods eaten. Only 8 larval midges were found in the stomachs. The great proportion of midges eaten were taken as pupae. These totaled 2,528 in the 14 stomachs in which they occurred. Quantitive samples of bottom foods discussed above (Table 1) indicated that midge larvae and pupae were the most abundant forms making up over 92 per cent of available bottom foods. It is interesting to note that midge pupae alone, in terms of numbers eaten, made up over 75 per cent of aquatic, and over 50 per cent of total foods eaten.

Midge pupae were taken in larger numbers than larvae by reason of the fact that pupae are easier to obtain. When they rise from the lake bottom to emerge as adults they are entirely unprotected and thus are easily secured by trout. The few larvae eaten indicates that the trout examined had fed but little directly on the bottom. If they had, undoubtedly more larvae would have been found in the stomachs, since no pupae whatsoever were taken in the bottom samples.

In terms of bulk or volume, fish eaten would of course be rated high, but only 7 fish had been eaten by the 35 trout. All of the trout that contained fish or the remains of fish in their stomachs, were over 8 inches in length and only one of them was less than 9 inches. One 21½-inch brown trout had 2 chubs, *Siphateles obesus,* in its stomach. Digestion of other specimens prevented classification to genera and species.

Other strictly aquatic foods eaten were 40 mayfly nymphs, 7 caddisfly larvae and a few alderfly larvae (*Sialis*), waterfleas (*Cladocera*), dragonfly and damselfly nymphs.

The dominant land foods eaten were ants, bees, and wasps (Hymenoptera). Members of this group totaled 1,106 or 66 per cent of terrestrial foods and occurred in 25 of the 35 stomachs. Beetles were second (occurred in 21 stomachs), forming slightly over 12 per cent, while

adult caddisflies formed 6.6 per cent (occurred in 6 stomachs) of terrestrial foods.

True bugs (Hemiptera) and adult flies (Diptera) were about equally numerous in the stomachs, each forming about 5 per cent of terrestrial foods. Other land foods eaten were a few spiders, plant lice and grasshoppers. Salmon eggs used as bait by fishermen were found in 3 stomachs. No scuds, *Hyalella azteca*, or oligochaetes were found in the stomachs.

Marked Trout Planted

Since eastern brook trout seemed well suited to the lake, two separate plantings of this species were made. On September 26, 1933, 5,028 averaging about 2 inches in length, and marked by removal of the right ventral fins were planted (Table 2). Again on June 26, 1935, 2,080 marked by removal of the adipose and left ventral fins and averaging about 5½ inches in length, were planted. Thus, one planting of large fish was made in the spring and one of small fish in the fall; and reference will be made to them using the terms "large" and "small" in the following discussion.

Table 2.—Marked eastern brook trout planted and caught in Upper Angora Lake

Item	Plant of 5,028 Sept. 26, 1933[1]	Plant of 2,080 June 26, 1935[2]
1935		
Number caught	154	473
Percentage of total planting	3.06	22.7
1936		
Number caught	63	60
Percentage of total planting	1.25	2.8
Total	217	533
Percentage	4.3	25.62
Ratio of total catch to planting	1:23	1:4

[1]Average total length 1.97 inches; marked by removal of right ventral fins. Average length determined from measurements of sample of 52 fish. None of these was caught in 1934.
[2]Average total length 5.3 inches; marked by removal of adipose and left ventral fins. Average length determined from measurements of sample of one hundred.

Marked Trout Caught by Anglers

None of the 1933 planting of small marked fish contributed to the catches of 1934. During the 1935 angling season 154 or 3 per cent of those planted, were taken. In 1936, 63 or roughly 1 per cent were taken; both catches together amounting to 4.3 per cent of the total number planted (Table 2). Survivors of the 1933 planting formed 19 per cent of total trout reported caught in 1935 and about 30 per cent of the catches of 1936 when the total catch was much less.

Of the 1935 planting of large eastern brook trout, 473 or 22.7 per cent were caught in the same season in which they were planted. In 1936 only 60 or 2.8 per cent more were taken, making a total of 25.6 per cent of the 2,080 planted. Marked fish of the 1935 planting formed

Table 3.—Summary of all trout reported caught in Upper Angora Lake, 1934-1936, inclusive

Species of trout	1934		1935		1936	
	Number	Percentage	Number	Percentage	Number	Percentage
Unmarked:						
Eastern brook trout....	47	52 8	176	21.7	61	29.0
Rainbow trout	25	28.1	1	0.1	12	5.6
Brown trout	17	19.0	5	0.6	15	7.1
Marked:						
Eastern brook trout....	0	.....				
Planting of 1933..	0	.....	154	19.0	63	29.8
Planting of 1935..	0	.....	473	58.5	60	28.4
Totals	89	.....	809	.....	211	.....

58 per cent of the total 809 trout caught that year. Marked fish of both the 1933 and 1935 plantings formed 77 per cent of the 809 taken in 1935 and 58 per cent of the 211 reported caught in 1936 (Tables 2 and 3).

The survival ratio of the 1933 planting of small eastern brook was 1:23; or 1 fish was caught for every 23 that was planted. The survival ratio of the planting of larger fish was approximately 1:4.

Sources of Error

The following sources of error make it necessary to consider the survival rates recorded here as minimal:

Migration from lake.—While the outlet was screened, doubtless a few marked fish left the lake when the screen became plugged with debris and water passed over it. Only one marked eastern brook trout, however, was caught in Lower Angora Lake and the fishing intensity there is almost as great as in Upper Angora Lake.

Incomplete returns.—The returns are estimated to be 95 per cent complete and but for the fact that a few anglers ate their fish first and reported afterwards, the returns would have been even more complete. One angler refused to allow his catch to be examined.

Priod covered.—Catch records used in calculation of returns to anglers should cover the average life-span of the marked fish planted. It is quite likely that when the work was ended in 1936 some marked eastern brook trout still remained in the lake. Even the heavy gill-netting operations conducted in October 1936, probably did not remove them all.

Costs

The cost of rearing the 5,028 small trout planted in 1933 was roughly $8.00 for food alone figured on the basis of 50 cents per pound of fish raised. The 217 caught cost 4 cents each on this basis. On the same basis, the cost was roughly 14 cents each for each of the 533 caught from the 1935 plant of larger trout.[2]

[2]These figures are approximations for they do not include fish caught in the gill-netting operations in October 1936, when 9 marked fish were caught; 6 from the 1933 planting and 3 from the 1935 planting. Neither do they take into account survivors of either planting which may have been missed in the gill-netting and which may have been caught in 1937 or later when no catch records were taken on Angora Lake.

In terms of *survival only,* the planting of larger eastern brook trout was more successful since over five times as many survived to be captured by anglers. In terms of *cost,* the plant of large trout was over three times as expensive per fish creeled. Big fish cost more to raise but their effect on a fishery is usually felt at once. The planting of large fish made in 1935 contributed 473 of the 809 trout taken in that year and we can safely assume then that if this planting had not been made, less than half as many fish would have been taken in Angora Lake that year. It is evident from this data that heavy stocking with a single species can completely change catches in a small lake in a short time.

The cost of rearing 2-inch fish for items other than food is higher proportionately than for 5-inch fish because on the basis of cost for food alone, yolk-sac fry would not cost anything since they would not have been fed prior to planting. But if, in addition to food, cost of the eggs, salaries, depreciation, interest on capital investment, or other items, are included, the cost per fish of the two plantings would be more nearly equal.

Why not plant heavily with small trout and save money? The answer obviously will depend on a large number of conditions. Food supplies definitely limit productive capacity and, if the *intensity* of angling overbalances productive capacity, then there is no alternative that we know of now but to produce the *poundage* in hatcheries and to plant big fish. If this is done certainly the bag limit should be reduced below that now in effect in California (25 fish or 10 pounds and 1 fish). If 5½-inch fish costing the State 14 cents each are planted, a resident angler who pays $2.00 for his license would exceed the cost of his license if he took only 15 of them. Obviously, in intensively fished waters wherein large, expensive, hatchery-reared trout are planted, not only should reduced bag limits be put into effect, but similarly seasons and size limits should be restricted as well. These measures have been adopted in many eastern states. It is desirable to obtain the greatest possible "spread" of fish among the largest number of anglers.

Spring Versus Fall Planting

One reason for the higher survival of the larger fish is that they were planted after the opening of the fishing season in June. The planting of small trout was made in late September and a number of workers have shown heavy losses to occur among fall planted fish in terms of returns to anglers' creels, particularly of plantings made in streams.

Surber (1936) reported returns of only 6.0 and 1.5 per cent, respectively, of 1,080 and 2,160 marked rainbow trout (average total length 4 inches) planted in the fall of 1934 and 1935 in Big Spring Creek in West Virginia. Nesbit and Kitson (1937) reported that spring-planted fish were over five times as successful as fall-planted trout

stocked in ponds and streams in Massachusetts, and stated that (p. 170) . . . "in no experiment was the percentage recaptured from fall-planted fish as high as from spring-planted fish" . . . and that the differences were less marked in the two ponds planted as compared with the three streams planted. Hoover (1937, p. 19) concluded that "Lake conditions are vastly different and it is believed from the data available, that trout should be stocked in most lakes during the fall months (after open season) . . ." though he did not present supporting evidence.

Hoover and Johnson (1937) recommended frequent, open season plantings instead of fall or early spring plantings on the basis of results from planting marked legal-sized trout in several New Hampshire streams. The fishing in Upper Angora Lake could be improved considerably by this method. Certainly this procedure would be justified in light of the intensity of the angling and the fact that its productive capacity will never come anywhere near meeting fishing demand. As reported by Needham (1937) the fishing in Conviet Lake, eastern California, was similarly bettered by a planting of 2,014 marked rainbow trout averaging 5.67 inches in length in July 1935. These marked fish formed 41 per cent of the total of 848 trout caught and represented 17.3 per cent of the number planted.

Shetter and Hazzard (1940) presented evidence that adult rainbow can be released in lakes in the fall with the expectation (p. 466) ". . . that at least from 50 to 70 per cent will be taken during the following season." They also found that fall planting of trout in Michigan streams did not pay, and obtained more than six times as many returns from early spring plantings of brook trout than from fall plantings. With rainbow trout the returns were 32 times greater and with brown trout, twice as great.

Hazzard and Shetter (1938) from incomplete records reported weighted recoveries of 19.8 per cent of 7,513 marked eastern brook and 17.5 per cent of 4,007 rainbow trout planted in the fishing season from May to August in the Pine River in Michigan. Actual percentage of capture varied from 4.9 to 40.2 per cent. In comparison Shetter (1939, p. 322), reporting on returns of tagged or marked fingerling trout also in Michigan waters, stated ". . . in no experiments have the returns (in the form of legal fish) been greater than 1.6 per cent of the total number of fingerlings planted." Surber (1940) reported a return of only 2.4 per cent to anglers from fall plantings totaling 11,107 large eastern brook and rainbow trout over a 3-year period in the St. Mary River, Virginia. The survivals given for Angora Lake are better, on the whole, than survivals reported for stream-planted trout and are in line with the observations of most fish-culturists that better survival of hatchery trout is obtained in lakes than in streams. In waters where good natural spawning conditions exist, and where all breeders are not removed annually, whether lakes or streams, creel census information is slowly building up an extremely

strong case for natural propagation (see Lord, 1935). From a creel census on Furnace Brook in Vermont, Lord reported a catch of over 8,500 legal trout in 1935. Rainbow trout made up over 34 per cent of the catch and eastern brook trout contributed 66 per cent, in spite of the fact that rainbow trout were not being planted and resulted entirely from natural propagation. Similarly, the take of eastern brook trout exceeded the number planted before the end of the first fishing month.

Evidence is rapidly piling up that natural propagation furnishes the major portion of fish caught by anglers and this fact emphasizes the need for protection of adequate brood stocks to insure maximum production of native fish. Spawning bed improvements might materially aid natural propagation where conditions for reproduction are lacking or inadequate.

Gross Returns of All Trout

While some discussion of total trout captured each year has been given above, it is of interest to compare the relative numbers of both unmarked and marked trout, as well as the numbers of each species that were taken each year. In Table 4, the complete records are summarized for each year from 1934 to 1936, inclusive. In 1934 only 89 trout were reported caught. As noted above, none of the small eastern brook planted in 1933 appeared in the catches that year. Unmarked eastern brook trout formed over 52 per cent of the take of 89 fish. The others taken were 25 rainbow trout and 17 brown trout, which made up 28 per cent and 19 per cent, respectively, of the 1934 catch.

Only 39 catches were reported in 1934 and these averaged 2.2 fish per angler, a comparatively light effort for a lake as accessible as Upper Angora.

The 1935 take of trout showed an increase of over 9 times that of 1934. A total of 809 trout were taken in 136 catches reported; an average of 5.9 fish per catch. Marked eastern brook trout from the plantings of 1933 and 1935 entered catches for the first time and

Table 4.—Number and weight of trout captured in Upper Angora Lake, 1934-1936, inclusive

Species	1934			1935			1936		
	Number	Total weight (pounds)	Percentage by weight	Number	Total weight (pounds)	Percentage by weight	Number	Total weight (pounds)	Percentage by weight
Eastern brook trout:									
Unmarked	47	22.1	28	176	45.7	43	61	21.4	25
Marked:									
Of 1933 planting	0	.....	....	154	13.4	13	63	12.3	14
Of 1935 planting	....	.....	....	473	38.9	37	60	7.7	9
Rainbow trout	25	27.2	34	1	1.2	1	12	11.1	13
Brown trout	17	29.7	38	5	6.8	6	15	32.8	39
Totals	89	79	....	809	106.0	....	211	85.3	....

formed over 77 per cent of total trout taken. Over 21 per cent or 176 of these were unmarked eastern brook trout, while only 5 brown trout and 1 rainbow trout were taken. Eastern brook trout contributed over 99 per cent of all fish taken in 1935, while in 1934 this species formed only 52 per cent of all fish caught. This is concrete evidence that intensive stocking with a single adaptable species in a small lake can quickly improve the take.

Catches in 1936 still produced marked eastern brook trout in goodly numbers, when they constituted more than 58 per cent of all fish landed, but the total take fell to only 211 fish, about one-fourth of the 1935 catch. The reason for the decrease must have been scarcity of fish rather than lack of effort, because the take of brown trout increased from only 5 in 1935 to 15 in 1936. Similarly captures of rainbow trout increased from 1 in 1935 to 12 in 1936. Brown trout of large size are "cagy" and skilled in eluding lures. The fact that the total number captured in 1936 decreased, but that the number of brown trout increased correspondingly, leads one to believe that the effort must still have been high, but that scarcity of fish was the basic cause for a lowered return.

In 1936, 89 catches were reported which in turn gave an average of 2.4 fish, a drop of 3.5 fish per catch from the average of 5.9 for 1935. This was close to the 1934 average of 2.2 fish per catch. Clearly the fishing produced by the plantings was of short duration. If planting is to be effective it must be done often and this is especially true of larger fish.

Growth of Marked Trout

Lengths and weights were recorded and scale samples were taken from 9 marked eastern brook trout caught in gill nets in 1936. Six were of the 1933 planting; their average length was 9.8 inches and average weight, 6.2 ounces when caught. During 3 years in the lake their average growth increment was 2.6 inches in length and 2 ounces in weight per year.

The three fish of the 1935 planting averaged 7.6 inches in length and 2.2 ounces in weight when caught and showed an increase of 43 per cent in length and 91 per cent in weight over their planted size in the 15½ months they were in the lake. The growth per year at this rate was 1.7 inches in length and 0.82 ounces in weight.

In spite of the fact that both lots of fish were in their first year of life at the time of planting, the fish stocked in 1933 grew faster than those introduced in 1935. This difference in growth rate was expected since the 1933 planting consisted of fish averaging 1.9 inches in length, while the 1935 planting was of fish averaging 5.3 inches long, and it is known that smaller trout normally grow faster than larger ones under the same environmental conditions.

In the 1935 catch, the fish of the 1933 planting averaged but slightly heavier (1.39 ounces) than those of the 1935 planting (1.31 ounces);

and in 1936 the 1933 fish had gained during the year an average of 1.71 ounces to the 0.75 ounce gained by 1935 fish.

Weight of Fish Captured

As stated above, all fish were weighed when anglers reported in at the resort at the end of any single period of fishing. In Table 4 the total weight and number of all fish taken along with the percentage by weight for each species are listed.

In 1934, the 47 unmarked eastern brook trout weighed a total of 22.1 pounds, forming 28 per cent of the 79 pounds of trout taken. Their average weight was slightly below 0.5 pound. Rainbow trout and brown trout contributed similarly at 34 per cent and 38 per cent, respectively. The average weight of rainbow trout was approximately 1 pound, while the brown trout averaged 1¾ pounds.

In 1935, because of the large return of marked and unmarked eastern brook trout, this species contributed 93 per cent of the 106 pounds of trout taken. Brown trout totaled only 5 in number and 6 per cent by weight and only 1 rainbow trout was taken.

In 1936, production fell to 85.3 pounds, 20.7 pounds less than was reported in 1935. While only 15 brown trout were taken, they averaged 2.18 pounds each and contributed 39 per cent of total poundage caught. Eastern brook trout formed 48 per cent by weight of all trout taken in 1936.

Production per Acre

The sudden increase in fish creeled in 1935 as compared to the other 2 years is even more striking if our figures are reduced to a number per surface acre basis as in Table 5. The average number of fish taken per

Table 5.—Number and pounds of all trout caught per surface acre in Upper Angora Lake, 1934 to 1936, inclusive[1]

Catch per acre	Year	Pounds per acre
17.8	1934	15.8 lbs.
161.8	1935	21.2 lbs.
42 2	1936	17.0 lbs.

[1]The estimated surface area of Upper Angora Lake is 5 acres.

surface acre was 17.8 in 1934, rising to 161.8 in 1935, and dropping again to 42.2 per acre in 1936.

In terms of pounds per surface acre, the 1935 increase is not so striking. In 1934, 15.8 pounds of trout landed in anglers' creels per acre; in 1935, 21.2 pounds; and in 1936, 17.0 pounds. These figures are close to those reported by Eschmeyer (1937) for three "pot hole" or pit lakes in Michigan, ranging from 4 to 6 acres in area who calculated a production of from 4.3 to 30 pounds per acre. Needham and Cliff (1938) reported that Fish Lake and in the Cascade Mountains of Oregon produced 66 trout or 20 pounds per surface acre landed in

creels in 1937. It is interesting to note that Surber (1936) in studies on Big Spring Creek in Virginia, found that over a 4-year period production averaged very close to 30 pounds per acre, roughly 10 pounds more than Upper Angora Lake.

Age of Trout Caught

In Table 6, a total of 89 trout are grouped according to age and species. Age was determined by an examination of the scales and scales from marked eastern brook trout of known ages were used in checking the ages of the unmarked eastern brook included in Table 6. With the rainbow trout and brown trout it was not possible to check the age determinations against scales from fish of known ages.

Twenty-seven of the 47 eastern brook trout caught were in their third year of life and showed a much larger, and from an angling standpoint, a more desirable proportion of incoming young fish than was evident with the rainbow trout or brown trout population. Seven specimens were in their second year of life, while only one was in its fifth year.

Evidence of successful natural propagation of eastern brook trout was obtained by seining in shallow water on the north shore of the lake in October 1936. Two fish in their first year were taken; one was 2.4 inches and the other 2.2 inches long. A few other specimens of the same age group were observed but not caught. These one-year fish could only have been the result of natural spawning in the lake itself, as no fish of this age and size had been planted since 1933, and the outlet was screened to prevent fish passing in and out of the lake.

Sixteen of the 24 samples of scales from rainbow trout possessed four definite annuli, indicating that the fish were in their fifth year. Five were in their sixth year, two in their fourth year, and only one was in its third year. No young rainbow trout in their first and second years of life were represented in the material examined.

Table 6.—Age groups of trout from Upper Angora Lake as determined from scale studies.[1]

Species of trout	Number	Age Group									
		[2]1	2	3	4	5	6	7	8	9	10
Eastern brook	47	2	7	27	10	1	..	..	..	..	..
Rainbow	24	..	..	1	2	16	5	..	..	..	..
Brown	18	..	..	..	..	3	9	2	2	1	1(?)

[1]Based on the following fish: Eastern brook trout, 31 averaging 9.6 inches (total length) caught by anglers in 1934, 14 averaging 9.1 inches gill-netted in 1936, and 2 of year averaging 2.3 inches caught by seining in 1936; rainbow trout, 2 averaging 13.7 inches caught by anglers in 1933, 21 averaging 13.4 inches caught in 1934, and one 9.7 inches in length gill-netted in 1936; brown trout, 14 averaging 16.4 inches caught in 1934 and 4 taken in the gill-nets in 1936 that averaged 22.3 inches in length. Since only weight, number and species of fish was recorded from anglers' catches, for the purposes of this table and the length frequencies in Fig. 2, it seemed desirable to lump all actual measurements into 1 sample even though not all were taken in the same year or by the same method since the data thus combined would appear to offer a clearer picture of the fish population of the lake over the period covered.

[2]Indicates fish in first year, though it may not yet have completed it; often designated the "0" group.

The brown trout ranged between fish that were in their fifth year to one specimen that may have been in its tenth year. Nine of the 18 were in their sixth year of life. No fish younger than 5 years was taken.

The last planting of rainbow trout made in Upper Angora Lake was in 1930. Since fish less than 1 year old were planted then, and since most of the rainbow trout taken were in their fifth year, these fish could be survivors of that planting. However, the two fish in their fourth, and one fish in its third year, respectively, probably came from natural spawning in the stream between Upper and Lower Angora Lakes, since they were not old enough to be survivors of the 1930 planting. All three species of trout in the lake might originate from natural spawning in the stream between the lakes prior to the time the outlet of Upper Angora Lake was screened, in the spring of 1934, in connection with the present study.

Rainbow trout and brown trout might have spawned in the gravel of the shore of the lake itself. The senior author has seen rainbow trout nests in gravel beds in high Sierra lakes, and observed fish apparently spawning in them. However, definite evidence, such as collection or observation of young fish produced under these conditions, is lacking to date. It is believed that brown trout never spawn successfully in lakes.

Eastern brook trout are known to spawn in lakes, and lake-spawned young of this species were collected in the present study, as was noted just above.

In Figure 2 is presented a length frequency distribution of each group of trout upon which the age determinations from scale readings were based (Table 6). Good agreement is evident between Figure 2 and age groups as presented in Table 6. Hoover (1938) mentioned a definite need for a study of scales from trout of known ages to ascertain if conventional methods of scale study are valid.

Gill-net Catches

It would have been desirable to continue the catch record work over the average life-span of the marked fish, but lack of funds made it necessary to conclude the Angora Lake work at the close of the 1936 angling season. In order to obtain as complete data as possible on trout remaining uncaught in the lake, it was decided to fish the lake heavily with gill nets and to follow this operation with a planting of a substantial number of fair-sized trout to compensate for the fish destroyed by netting.

A total of 18 gill-net sets were run totaling 403.6 hours of fishing. Two nets were used, each 125 feet long by 6 feet deep. One contained 5 sizes of mesh varying from 2 inches down to ¾-inch mesh, while the other was entirely of 2-inch mesh bar measure. Each net was fished an average of 22.4 hours per set.

The results of the gill-net catches are summarized in Table 7. A total of 44 fish was taken, 25 or 56.8 per cent were the lake chub,

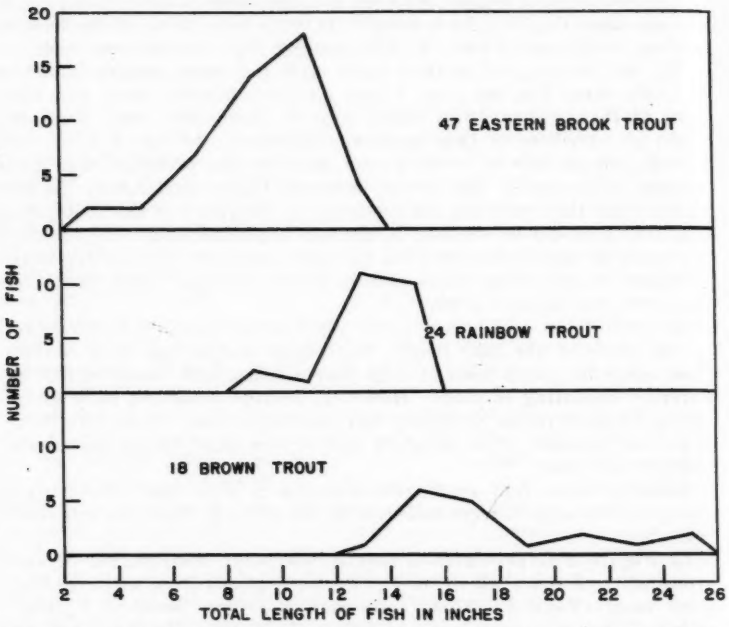

Figure 2.—Length-frequency distribution of eastern brook trout, rainbow trout, and brown trout caught in Upper Angora Lake in 1935 and 1936.

Siphateles obesus. Only 14 eastern brook trout (31.8 per cent), 4 brown trout (9.1 per cent), and 1 rainbow trout were taken. No bluegill sunfish was taken. Assuming then that the gill nets exhibited no selective action with reference either species or sizes of fish and that all species were taken at the same rate, of every 100 fish in Upper Angora Lake, 57 would be lake shubs, 32 eastern brook trout, 9 brown trout, and 2 would be rainbow trout.

The average catch per hour of net fishing was 0.11 for all fish. This rate is extremely low and indicates that the fish population of Upper Angora had fallen to a low level at the end of the 1936 season. Additional evidence lies in the fact that total trout caught by anglers fell from 809 in 1935 to only 211 in 1936.

The four brown trout caught varied from 2 to 7 pounds in weight and from 16 to almost 26 inches in length. All were old, predacious cannibals that undoubtedly had consumed many young trout as well as chubs and, with the other large specimens removed by anglers, must have accounted in no small degree for the low survival rates obtained

Table 7.—Fishes collected in eighteen gill-net sets in Upper Angora Lake October 1936[1]

Species	Total number caught	Percentage	Average total length (inches)	Range in size (inches)
Eastern brook trout[4]	14	31.8	9.1	6.1-13.6
Brown trout[5]	4	9.1	22.3	16.3-25.6
Rainbow trout	1	2.3	9.7	.....
Lake chubs[6]	25	56.8	.....	[2]4-7
Totals	[3]44	.....	.....	.....

[1]The nets were fished a total of 403.6 hours.
[2]Estimated size.
[3]Average rate of catch was 0.11 fish per hour.
[4]Marked fish—9; from 1933 planting—6; from 1935 planting—3.
[5]Total number consisted of 3 males, 1 female, all mature and ready to spawn. Range in weight 2.0 to 7.0 pounds.
[6]Identified as *Siphateles obesus* by Dr. Carl L. Hubbs.

from the plantings of small eastern brook trout. Fry (1939) and others have pointed out that there are more small trout when there are fewer large ones present.

Reflection on the presence of the brown trout and their size and age, leads one to consider that Angora Lake would have been infinitely better off if brown trout had never been planted there. There was no evidence of natural reproduction as was found with eastern brook trout, and the 37 taken by anglers from 1934 to 1936 were evidently survivors of earlier plantings that contributed but little sport to anglers and at the same time maintained themselves at the expense of the more desirable species. Brown trout are well known to produce better fishing in warmer waters at lower elevations.

After brown trout have been planted in waters to which they are not well-suited but in which they can survive, their removal might prove to be distinctly beneficial management measure. Gill nets could be used as they were in the present instance, or traps, poisons, or other methods. Poisons such as derris root or blue-stone are expensive unless the volume of water to be poisoned is small. The use of gill nets or traps would not destroy entire fish populations as most poisons do and the use of nets with large-sized mesh, over 3 inches "bar" measure, should be quite selective in action and kill only old fish of large size. Since large brown trout cannot or do not spawn in such cold lake waters, they should be eliminated for more adaptable species. The control or elimination of big, carnivorous brown trout or trout of other species by selective gill-net fishing might offer a practical means toward securing better survival rates of fish whether planted from hatcheries or naturally spawned.

Coarse Fish Problem

Evidence from the gill net catches (Table 7), clearly indicates that the dominant fish in Upper Angora Lake are lake shubs, *Siphateles obesus*. These undoubtedly were introduced as bait used or discarded by anglers, which is the usual way bait fishes become stocked in non-native waters. Such "scrap" or "coarse" fish frequently become so

abundant as to completely dominate the fish population in lakes that might otherwise provide excelent trout fishing. Heavy populations of stunted yellow perch (*Perca flavescens*) or bluegill sunfish do the same thing in eastern lakes. Lake chubs compete with trout for food and since trout are removed by anglers and chubs but seldom caught, angling therefore serves to aid in their development by reducing the number of game fish that might utilize them as food.

Carl and Hodgson (1937) reported killing over 20,000 chubs in Lower Loch Leven Lake near Cisco, California, by dynamiting in an attempt to reclaim a 10-acre water area that had apparently been taken over by lake chubs and they reported that only 4 brown trout were destroyed with the chubs. In an Oregon lake, 18 dump-truck loads of lake chubs were destroyed in poisoning with derris root.[3]

Derris root, referred to above, has been used with apparent success to poison other lakes in California and elsewhere to destroy heavy chub populations and several workers have reported successful use in both trout and non-trout waters. Some control doubtless is desirable to aid in reducing or exterminating dense populations of competing non-game species. Such control permits growth and reproduction of larger numbers of game fishes to a reasonable catchable size increasing the annual take correspondingly. The writers are convinced that Upper Angora Lake and many other high mountain lakes would offer much better trout fishing if both the chubs and large brown trout were removed. Certainly chubs do not offer food to medium sized trout but only to the larger carnivorous forms which might better be removed.

Results of this study are summarized in the abstract at the beginning of the paper.

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STANDARD LENGTH VERSUS TOTAL LENGTH

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ABSTRACT

In an effort to determine the length measurement most representative of the bulk of the fish, the standard length and the total length were each compared with the weight of the fish. This comparison was made for four species of game fish, yellow perch (*Perca flavescens*), wall-eyed pike (*Stizostedion v. vitreum*), rock bass (*Ambloplites rupestris*), and lake trout (*Cristivomer n. namaycush*). In each of the four species it was found that the weight could be estimated more accurately from the total length than from the standard length although with the wall-eyed pike the difference was inconsequential. Other advantages of the use of total length were outlined briefly.

An analysis carried out in an attempt to determine the reason for the greater accuracy of weights estimated from the total length revealed that in a sample of yellow perch, the length of the caudal peduncle exhibited more variation than did the length of the caudal fin. It was determined further that these two measurements tended to be negatively correlated, that is, the yellow perch with longer than average caudal fins tended to have shorter than average caudal peduncles and vice versa.

INTRODUCTION

Ichthyologists and fishery biologists seem fairly well agreed that in the measurement of the length of fish the tip of the snout marks the anterior end. However, the point to which the length is measured on the posterior end varies considerably. For example, Table 1 illustrates the diversity of measurements used by authors in the *Transactions of the American Fisheries Society*, Vol. 70.

Standard length was defined by Jordan (1905) as the length of a fish from the tip of the snout to the end of the caudal peduncle. The end of the caudal peduncle is not a very definite point, and most ichthyologists now regard the standard length as the length to the anterior swelling of the hypural plate, or in other words, to the end of the unmodified part of the vertebral column. Other investigators use the length to the last scale in the lateral line, to the end of the fleshy part of the caudal peduncle, or to the posterior limit of scalation on the caudal peduncle.

These methods are further complicated by differences in the anatomy of the tail among fish of different sizes and species. The standard length is even less accurately defined for fish possessing other than the homocercal type of tail.

Moreover, other practical difficulties present themselves. Less experienced workers do not measure the standard length to the end of the vertebral column as accurately as they measure total lengths. The actual end of the vertebral column is often difficult to find. Furthermore, the operation of measurement requires two hands, one to hold

Table 1.—Length measurements of fish used by authors in the TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY, *Vol. 70*

Measurement used[1]	Number of authors using measurement
Standard length only	4
Fork length only	2
Total length only	3
Standard length and total length	1
Length to end of caudal peduncle and fork length	1
Length to last scale in lateral line	1
Standard length, fork length, and total length	1
Length measurement not specified	4

[1]Several others who made only a brief reference to 6-inch fish, legal-sized fish, etc., were not included in the above list.

the fish and the other to manipulate a straight edge to find the end of the vertebral column.

In support of the use of the standard length is the fact that preserved specimens often acquire broken tails and this length is the only one that can be taken. In the great body of taxonomic literature the standard length only is used. Most workers have also thought that the length of the caudal fins of fishes tended to vary greatly and that the standard length was therefore the most representative measurement.

The total length of a fish is likewise measured in a variety of ways: (1) From the tip of the snout to the fork of the tail; (2) to the tip of the tail with the tail spread in its natural position; and (3) to the tip of the tail with the rays pressed together to make the maximum total length possible. The maximum total length is the fisherman's length and is the length on which legal restrictions are ordinarily based. It is more easily and rapidly measured, with less chance for error, than are other lengths. Measurements of total length to the fork of the tail and to the tip with the tail spread share some of the difficulties common to the standard-length measurements.

Nevertheless, many biologists have had qualms concerning the accuracy of total length and despite its greater usefulness have tended to avoid it. Consequently, it is of considerable importance to know whether the total length or the standard length is the more representative of the bulk of the fish. I first suspected that the total length was the more representative when I noticed that the "scatter" of the points tended to be less around a length-weight curve based on total lengths than around a curve based on standard lengths. A more definite test of the relative representativeness of the two measurements seemed desirable. Accordingly, I have determined for yellow perch, wall-eyed pike, rock bass, and lake trout the length measurement from which the weight may be more accurately estimated.

METHODS OF SECURING THE DATA

The standard length used in the following analysis is the length from the tip of the snout to the swelling in the hypural plate. The total length is the maximum measurable length, that is, from the tip

of the snout to the tip of the tail with the dorsal and ventral rays of the caudal fin held parallel. All of the fish were measured on the same accurately graduated measuring board and a knife edge was always used to find the swelling in the hypural plate.

All of the fish were measured to the nearest millimeter except the lake trout which were measured to the nearest one-eighth inch. All weights and measurements were made on fresh fish except the rock bass and the smaller lake trout which were measured and weighed from 1 to 2 months after preservation in formalin. No allowance was made for shrinkage due to preservation since this shrinkage should affect both lengths about equally, and the amount of shrinkage that has been determined by other workers is very small (almost always less than 2 per cent). Great care was used in weighing preserved specimens to remove surface moisture with a wet towel and to drain all liquid from the celom and air bladder. All lengths and weights were measured by me.

Analysis of Data

The lengths and weights were first transformed to three-place logarithms. Then regression lines were calculated from the length-weight data for both total length and standard length for each species. The logarithmic standard errors of estimate were obtained and since these correspond to a percentage deviation the coefficients of variation were found by taking the antilogarithm. All calculations follow the methods outlined by Snedecor, 1940.

Results of the Analysis

The results of the analysis are listed in Table 2. For each species, it may be seen that the weight could be estimated more accurately from the total length than from the standard length although with the wall-eyed pike the difference is inconsequential. The rock bass is the only species which shows a significant difference (by the *F*-test) between the two variances but the usual test of significance means little because the two variances are known to be interdependent to

Table 2.—Variation of the actual weight of fish from the weight estimated by means of the regression of weight on length

Species	Size, range and source of sample	Coefficient of Variation (Standard error of estimate as a percentage of the mean weight)	
		Weight estimated from standard length	Weight estimated from total length
Perca flavescens	34 specimens, 111 to 228 millimeters total length, from Conesus Lake, July, 1940.	8.1	6.3
Stizostedion v. vitreum	20 specimens, 222 to 491 millimeters total length, from Conesus Lake, July, 1940.	10.4	10.2
Ambloplites rupestris	53 specimens, 16.9 to 233 millimeters total length from Silver Lake, July, 1940.	9.8	7.1
Cristivomer n. namaycush	24 specimens, 9⅝ to 26 0/8 inches total length, from Keuka Lake, summer, 1940.	10.5	7.4

some extent. Consequently a less than significant difference may well be a real difference here. I believe it can be said safely that the total length represents the bulk of the fish better than the standard length in the yellow perch, rock bass, and lake trout. An analysis of the length-weight data based on the fork length was also made for the lake trout. The coefficient of variation was 7.7 per cent, a value intermediate between the coefficients obtained with the use of standard length and total length.

I do not believe that the difference observed between the two length measurements can be attributed to simple mistakes in measurement. The measurements were not completely repeated but many of the fish were measured twice. These duplicate measurements indicated that both of the length measurements were within 1 per cent of the true value. Furthermore, the rock bass, the species which was measured entirely under laboratory conditions showed the greatest difference between the two coefficients of variation.

An attempt to learn whether the variation originated in differences in body proportions of individual fish was made by measuring the length of the caudal peduncle and the length of the caudal fin in a sample of 40 yellow perch, 9 to 12 inches long, taken in May 1941, in Otsego Lake. The coefficient of correlation between the lengths of the caudal peduncles and the lengths of the caudal fins (both expressed as percentages of the total length) was —0.306. With 38 degrees of freedom this value is on the borderline of significance. Thus, it is possible that fish with caudal fins that are longer than average tend to have caudal peduncles that are shorter than average and vice versa. It is interesting to note that the length of the caudal peduncle showed a coefficient of variation of 4.0 per cent whereas the length of the caudal fin showed a coefficient of variation of 3.5 per cent. These results are by no means conclusive but do indicate that the caudal fin is perhaps not the more variable part of a fishes body.

Some Practical Considerations

If critical comparisons are to be made between the work of different investigators some standardization of length measurements is eminently desirable. If one measurement is more representative of the fish than others, why not use it? The efficiency of the standard length may be easily checked against that of the total length for any species of fish by transforming the lengths and weights to logarithms and plotting them on graph paper or by plotting the real numbers on logarithmic paper. After a straight line has been drawn through the center of each group of points any great difference in the "scatter" of the points about the line can be seen readily.

In the handling of large numbers of fish it would save time to take only the more representative length measurement. If it is desired, for example, to prepare a length-weight curve for the rock bass that is accurate within certain limits, more specimens will be required if

standard length is used than if total length is employed. According to the formula, $n = 9\ C^2/p^2$ (Snedecor, 1940, page 392), in which $n =$ the number of specimens necessary, $C =$ the coefficient of variation, and $p =$ the allowable percentage deviation from the true mean ($9 = t^2$ with t taken as 3), it would require 216 specimens to estimate the mean weight of rock bass from the standard length to within 2 per cent, whereas with the use of total lengths the same degree of accuracy could be attained with only 114 specimens. Similar considerations apply to the computation of condition factors or to other operations involving the length-weight relationship of fishes.

Conclusion

The standard length is not necessarily more representative of the bulk of the fish than is the total length. A summary of this paper may be found in the abstract.

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COMPARISON OF BOTTOM FAUNAS AS SOURCES OF AVAILABLE FISH FOOD

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ABSTRACT

To obtain a true estimate of the actual quantity of fish food which any fauna represents, allowance must be made for the differences in the availability to the fish of the various component species. The ratio between the percentage occurrence in a sample of stomach contents and in samples of the corresponding bottom fauna has been suggested as a measure of the availability. The theoretical basis of this ratio—the "forage ratio" or "availability factor"—is discussed, and it is shown to be essential, when using this factor in comparing faunas as sources of available food, to use the ratios as determined and without change, and to apply the same series of values to all the faunas being compared. The availability of a food animal varies in respect not only to the species but also to the size of the fish concerned. Comparisons of faunas should therefore be based on two or more determinations of the "apparent available density" of each, these being made in respect to different size groups of fish present. The same arbitrary standards for the classification of fauna can be applied to the apparent available densities as to the actual densities of the fauna. Availability factors and apparent available densities can be determined on a numerical or gravimetric or volumetric basis. The numerical determination of availability factor is the most simple, and results obtained in this way can probably be applied satisfactorily to volumetric or gravimetric determinations of density.

Sufficient bottom samples should be taken to minimize the sampling error in determining the mean faunistic density, and all types of environment should be proportionately represented. Seasonal variation both in the density of the fauna, and in availability factors, should be allowed for by sampling at several times of the year. Samples should not be taken soon after floods. Further work is required on methods of eliminating inaccuracies due to selection by the fish and to different rates at which animals are digested.

The estimation of the food supply available to the fish population of a given water forms one of the major phases of fishery investigation, both from the practical aspect of determining stocking policies and in connection with more fundamental investigations of the relation between fish stocks and food supplies. In the past, estimations of food supply have usually been based only on the determination of the total bottom fauna present, and arbitrary standards have been drawn up by which a stream may be classified in respect to "food-grade" according to the number and volume of animals occurring in an average square foot of bottom (Davis, 1938). This procedure is based on the assumption that all the types of animals in the bottom fauna are utilized as food in proportion to their abundance. Comparison between the food actually eaten by fish and the corresponding fauna shows, however, that there are great variations in the relative extents to which different animals are eaten. It has been suggested by Hess and Swartz (1941)

and by Allen (1941) that a measure of the relative extent to which an animal is eaten is provided by the ratio between its percentage occurrence in the stomach contents of a sample of fish and its percentage occurrence in the samples of the bottom fauna taken at the same time and place. In order to determine the best method of applying the results obtained in this way to the evaluation of faunas as food supplies the actual significance of the ratio concerned must be considered. It appears probable that the different ratios found for various animals reflect differences in the extent to which they are available to the fish as food. Both Allen, and Hess and Swartz, have shown that there appears to be a correlation between the "forage ratio" or "availability factor" of an animal and various features of its size, structure and habits, which probably affect its availability to the fish. Thus the availability factor appears to bear a definite relationship to the extent to which a species is available, although it is not in itself a direct measure of the availability. For every animal there is an absolute availability at any moment which may be defined Allen (1941) as "... the proportion of the population which in a typical habitat would be visible to and of suitable size and taste to be eaten by a fish of the species under consideration, if the fish had the whole area under observation." It has been shown that for any one comparison between food and fauna the ratio of the availability factor to the absolute availability is $\frac{100}{\Sigma Ap}$: 1, where A_1, A_2, etc., are the absolute availabilities of animals with percentages in the fauna given by p_1, p_2, etc. Thus for a single comparison the ratio between the availability factor and the absolute availability is the same for all animals and may be called the "fauna constant." The fauna constant will, however, vary for different comparisons since the term ΣAp depends upon the composition of the fauna and the feeding habits of the fish. The absolute available density of any fauna is the sum for all the component species of the products of the density and the absolute availability. The absolute availability of an animal cannot be determined by any methods yet developed, but the sum of the products for each species of the density and availability factor is equal to the product of the absolute available density of the fauna and the fauna constant. This quantity may be referred to as the "apparent available density."

Since in any comparison the availability factor of any species is the product of its absolute availability and the fauna constant, the ratios between the availability factors of the different animals will be the same as the ratios between their absolute availabilities. Consequently although the actual values will vary, the ratios between the availability factors of different animals will remain the same in different comparisons, and therefore mean values can be determined from any number of comparisons which are based on fish of the same type.

This is only possible if the availability factors are used without

modification. If they are modified by any system which alters the ratios between them, such as that proposed by Hess and Swartz (1941), in which values greater than 1.0 are reduced to 1.0 while lower values are left unchanged, these ratios will no longer be the same as those between the absolute availabilities and also will vary in different comparisons. The results of different comparisons cannot therefore be combined in order to determine a mean value. Further, since the availability factors, or "forage ratios," when so modified are no longer proportional to the absolute availabilities, the apparent available density calculated from these results no longer provides an index of the absolute available density, and hence does not permit of accurate comparisons between different faunas. For these reasons it is clearly essential that any attempt to estimate the food supply available in a given water by means of the availability factor method must be based on these factors as first determined and that they must not be modified in any way which will affect the ratios between them.

Since the apparent available density of a fauna is the product of its absolute available density and the fauna constant, it is necessary, in comparing the available densities of different faunas, to use the same series of availability factors in each case; in other words, to keep the fauna constant for all determinations. If the values found by any comparison of food and fauna are applied to the fauna on which the comparison is based, the resulting apparent available density will equal the actual density of the fauna concerned. Where modifications are made in the original availability factor, as in the method of Hess and Swartz, this does not occur, and apparent values for available densities can be obtained by applying to a fauna availability factors determined from a comparison in which the same fauna was employed. This is the method used by Surber (1941), and represents some allowance for the differences in availability of the different components in the fauna, since the total density is reduced in respect of the less available types. For the reasons detailed above, however, the available density or "effective food grade" determined in this way does not bear any definite relation to the absolute available density of the fauna, and therefore does not permit of accurate comparison between different faunas.

Ultimately, it probably will be possible to adopt a standard series of availability factors for all the important animals usually occurring in the bottom fauna, but until sufficient determinations have been made it appears advisable to adopt as standard for any investigation a series calculated from data obtained from one or more of the waters being studied. The first stage in the comparison of a number of faunas should therefore be the determination of a series of availability factors to be adopted as standard for the work planned. A single comparison, with an adequate number of samples, between a fauna and the food of fish feeding on it may be used, or the mean values may be taken from a number of such comparisons. If, however, the mean of

several comparisons is used care should be taken to ensure that the fish used for the examination of stomach contents are similar in size and age. This is necessary since the availability of any food animal varies not only with the species of fish but also with the size, and possibly with the age, of the latter. Among fish of similar habits it appears probable that changes with the size are of greater significance than the differences between species. The stream-living species of Salmonidae provide an illustration of this point, since not only do the larger food animals become more available as the fish become larger, but also animals with hard shells or cases are less available to the smaller fish. Data have been obtained from as many sources as possible from which the average availability factors of the principal groups of bottom-living animals can be calculated for stream-living Salmonidae of various species and sizes (Table 1).

The writer's unpublished data used in this table and referred to elsewhere in the present paper have been obtained in the course of a study of the trout population of a New Zealand stream, the results of which it is hoped to publish in full as soon as conditions permit. The table does not show any significant differences between different species of fish but does show well-marked changes which take place as the size increases.

In the Ephemeroptera and Chironomidae there is a decrease in availability as the size of the fish increases, the decrease being very rapid in the latter case. On the other hand, the availability of Trichoptera and Mollusca increases with the size of fish, and the increase is particularly striking in the latter group. These changes are in accordance with the general tendencies outlined above. The Chironomidae and Ephemeroptera are soft-bodied forms, the former being

Table 1.—The approximate mean availability factors of the principal groups of bottom-living animals, determined from suitable data for various species and sizes of stream-living Salmonidae

Source of data	Species of fish	Age-group	Approximate size-range (centimeters)	Groups of bottom-living animals							
				Chironomidae (larvae)	Other Diptera (larvae and pupae)	Ephemeroptera	Plecoptera	Trichotera (larvae)	Mollusca	Coleoptera (larvae)	Oligochaeta
Allen (1941)	*Salmo salar*	0	2.5- 9	1.1	1.4	3.1	0.8	0.6	0	0.1	0
Pate (1933)	*Salvelinus fontinalis*	....	5-13	....	[1]0.4	2.4	0	0.2	..	0.2	..
Allen (1941)	*S. salar*	I	6-14	0.8	1.1	2.5	0.8	2.5	0.5	0.03	0
Pate (1934)	*S. fontinalis*	....	4-19	....	[1]0.25	0.5	1.7	0.5	0.5	0.1	..
Pate (1933)	*Salmo trutta*	....	5-16	....	[1]0.4	4.9	0.7	0.6	..	0.2	..
Allen (unpublished)	*S. trutta*	0	2 5-20	0.4	0.5	4.4	0.9	0.4	0.2	0.02	0
Needham (1938)	*S. fontinalis*[2]	....	10-25	....	[1]1.1	0.8	0.2	2.1	..	0.4	..
Allen (unpublished)	*S. trutta*	I	15-30	0.02	0.08	1.4	0	1.3	1.9	0.01	0
Ditto	*S. trutta*	II	25-40	0.003	0.01	1.0	0.7	1.5	1.3	0	0
Neill (1939)	*S. trutta*	....	30-35	....	[1]0.9	1.2	1.0	2.1	1.3	0	0

[1]Chironomid larvae not separated from other Dipte a.
[2]Sample of 147 fish; predominantly *S. fontinalis* but included 32 *S. irideus* and 6 *S. trutta.*

very small, while the majority of the Trichoptera and Mollusca have hard cases and shells, respectively.

Owing to the variations in availability with the size of the fish, a true comparison of the available densities of different faunas cannot be based on a single determination of the apparent available density of each, unless for any reason the fish inhabiting the areas are exceptionally homogeneous in size. In normal examples, separate series of availability factors and separate apparent available densities should be determined for two or more size or age-groups of fish. This procedure is necessary since a fauna which is highly available to small fish has not necessarily an equally high availability for large fish, and conversely. The method of combining the results for the different groups of fish will depend upon the purpose for which the faunas are being compared. In general, a mean "apparent available density" can be obtained by combining the results in the proportions in which the corresponding fish occur in the stock, either as already existing or as it is anticipated to exist after stocking. For this purpose the proportions of the various groups of fish should be determined on a gravimetric basis.

The following procedure should therefore be adopted in comparing the apparent available density of the faunas of different waters; a standard series of availability factors is first determined from one or more comparisons between a fauna and the food eaten in the same area. This standard series is then applied to all the faunas under investigation by multiplying, for each fauna, the density of each type present by its availability factor and then determining the sum of these products. As the component species of a systematic group form different proportions in different waters and frequently, as in the Ephemeroptera and Trichoptera, have very varied availability factors, only those animals should be grouped together for the determination of availability factors, which are very similar in size, habits and appearance. Separate availability factor and density determinations should therefore be made for each clearly distinguishable type in the fauna. Complete separate determinations should be made in respect to different size or age-groups of the fish concerned.

Where it is desired for practical purposes, such as determining stocking policies, to classify waters according to their food supply a much more reliable basis is provided by the apparent available density than by the actual density of the fauna. For this purpose arbitrary standards of apparent available density may be adopted, of the same type as those suggested by Davis (1938) for classification on the basis of the actual density. It has been shown above that, for any comparison, the value of the fauna constant is such that, when the resulting availability factors are applied to the fauna used for the comparison, the value obtained for the apparent available density is equal to the actual density. Consequently if the fauna of a typical stream or series of streams is used for determining the standard series

of availability factors to be applied in comparing a number of faunas, the average apparent available density will be approximately equal to the average actual density of the faunas compared. Therefore, any arbitrary standards of actual density which are used satisfactorily for the classification of waters may be applied unchanged to classification on the basis of the apparent available density.

As has been pointed out by Hess and Swartz, availability factors can be determined and applied either on a numerical or on a volumetric or gravimetric basis. Determination on a numerical basis is much the most simple in practice, since the complete separation of the various types from partially digested stomach contents, which is necessary for volumetric or gravimetric determinations, is a laborious and inaccurate process. On the other hand a more satisfactory and informative value for the density of a fauna is probably obtained by a volume or weight measurement. The values for availability factors obtained from numerical results will differ slightly from those obtained volumetrically or gravimetrically, since there is frequently a tendency for animals of a certain size range to be eaten to a greater extent than others of the same species outside that size range. It is doubtful, however, whether these differences are of great extent, and it is therefore probably satisfactory, if desired, to apply availability factors obtained on a numerical basis to volumetric or gravimetric measurements of faunistic density.

In comparing the available densities of faunas there are a number of sources of inaccuracy which require consideration. These may be examined in two categories; errors in the actual density, and errors in the availability factor. One of the principal sources of error arises in the normal course of sampling. Studies of the density of bottom fauna are customarily based on the examination of a number of quantitative samples of the stream bed, each sample being 1 square foot in area. As a result of the uneven distribution of the fauna considerable differences, both in the total number and the proportions of the various species, occur between samples taken under apparently similar conditions. The extent of these differences is clearly shown by the results of Mottley, Rayner and Rainwater (1939) and Leonard (1940). For this reason it is necessary to take a sufficient number of samples to insure that a reliable mean value is obtained. Hess and Swartz (1941) suggested that sufficient samples should be taken to keep the standard error within 10 per cent of the mean and this would appear to be a satisfactory standard for the purpose. In estimating the total available density for any water it is also necessary that the faunistic samples taken should represent adequately and in due proportion the various environments, pool, rapid, weed-bed, etc., since considerable differences occur between faunas of different environments.

An accurate comparison between the available food supplies of different waters should take into account seasonal fluctuations in conditions and should therefore be based on faunistic collections taken

throughout the year and not only at one season. Where climatic and other conditions are similar for all the waters being studied it may be safe to assume that the seasonal fluctuations are also similar in type and extent and that consequently approximate comparisons can be made by means of single series of collections. Needham (1938) has, however, shown that the form of the seasonal faunistic fluctuations may vary greatly in different streams, and it is therefore advisable to base a comparison on several series of collections taken at different times of the year. Apart from regular seasonal fluctuations in the fauna, irregular fluctuations may also occur due to various environmental factors, such as floods, droughts and epidemics. While all these factors are known to be capable of affecting seriously either the composition or the density of the fauna, actual measurements of the effects have only been made in the case of floods. Tarzwell (1938) and Mottley, Rayner and Rainwater (1939) found that floods abruptly reduced the densities of the faunas being investigated by rather less and rather more than half, respectively. Even greater reduction in the fauna due to flood-action has been found in a New Zealand stream which has been studied recently. It is therefore clear that very misleading results regarding the normal food supply provided by any stream will be obtained if the samples are taken soon after serious flooding has occurred.

Inaccuracies in the estimation of availability factors also may occur if determinations are made only at one season of the year. Studies which have been carried out on the relation between the brown trout population of a New Zealand stream and its food supply have shown that the availability factors of many food animals show well-marked seasonal fluctuations. These probably arise from the seasonal variations which occur in the size of the animal concerned. Another source of possible error in the determination of availability factors has been pointed out by Hess and Rainwater (1939). There are considerable differences in the rate at which animals of different types are digested, and on account of this the stomach contents of a fish does not indicate exactly its most recent food. Since the availability factor should be based on the composition of the actual food, this effect will produce inaccuracies in the availability factors as determined from stomach contents, causing the ratio to be too high in the case of animals which are digested slowly and too low in the case of rapidly digested animals. This source of error may possibly be overcome by the use of a compensating factor determined for each animal on the lines suggested by Hess and Rainwater.

In addition to the availability of the food animals, selection by the fish probably also plays an important part in determining what animals are actually eaten. The existence and extent of selection is not easy to determine, and it is not at present possible to lay down any general principles with regard to it. The existence of selection has however been shown, and its influence on the composition of the food

discussed, in the case of the freshwater stages of the Atlantic salmon (Allen, 1941). It was found that definite selection is exercised by most of the fish which have more than a few animals in their stomachs, and that the effect of this selection is to increase the apparent availability factors of those animals most abundant in the available fauna. It was shown that in this instance more accurate availbility factors could be calculated by using, where possible, only those fish which had comparatively few animals in their stomachs. If further work should show that similar selection effects occur generally it may be desirable, when sufficient material can be obtained, to apply in other cases a similar limitation in the stomach-contents material used. Where it is impossible to obtain sufficient fish with only a few animals in their stomachs, as frequently occurs with larger fish, an alternative method of compensating for the effects of selection might be developed by reducing by a standard proportion the calculated available densities of the most abundant species in the available fauna. Much further work is, however, required regarding the extent and nature of the selection which is exercised by feeding fish, and studies should be made to determine whether, as some evidence appears to suggest, the extent of selection is in any way controlled by the density of the fish stock in relation to the food supply.

The principal features in the determination of the apparent available density or effective food grade of a fauna appear to be:

(1) The use of a standard series of availability factors for any comparison of faunas.

(2) That there should be no modification in the availability factors as directly determined, except possibly to compensate for variations in the rate at which different animals are digested.

(3) That separate determinations of availability factors and comparisons of available densities should be made in respect of different size or age groups of fish.

(4) That sufficient samples should be taken to permit a reasonably accurate mean fauna to be determined, and that all environments occurring in the water studied should be proportionately represented.

(5) That determinations both of actual faunistic densities and of availability factors should be made at several seasons of the year.

(6) That care should be taken to avoid making any determinations soon after floods.

(7) That the possible influence of selection on the determinations of availability factors should be investigated and if necessary methods of eliminating this developed.

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CHANGES IN VOLUMETRIC MEASUREMENT OF SALMON EGGS

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Whether the volume of a salmon egg increases during incubation perhaps has not been determined; but, that the volumetric measurement of an aggregation of eggs increases during this period is either known or suspected by most hatcherymen. To determine the amount of the increase in sockeye salmon eggs, an experiment was undertaken by the writer in the autumn of 1932 at Rivers Inlet Hatchery in British Columbia.

The eggs used were spawned on October 21, and were well blended in the hardening tub from which they were measured into four lots of 42 fluid ounces each. The lots were retained in four standard hatchery baskets and a fifth basket from the same tub was retained for replacement of losses in the experimental lots. The measure used was a cylindrical can, the height of which was about twice the diameter. The eggs were poured into the measure, partially filled with water, and stroked off the top by means of a straight-edge. Measurements made by this method proved to be very uniform. In remeasuring the lots, the excess volume removed by the straight edge was measured in a graduated cylinder. When dead eggs were removed from the baskets they were replaced by an identical number from the fifth basket.

When the first remeasurement was made on October 23 it was found that the volume of each lot had shrunk to 41 ounces and 1 ounce was added to each lot to fill the measure. Subsequent measurements were recorded for the respective lots as shown in Table 1.

The measurements show first decrease of 2.4 per cent and then an increase of 9.5 per cent or a gross increase of 11.9 per cent in volume. These results do not necessarily indicate a change in size of the eggs, for in eyed eggs a friction develops which permits them to be heaped in a pile while green eggs will "run" or spread. This characteristic probably causes green eggs to pack more densely in a container than eyed eggs. With reference to the decrease in volume in the first 2 days after the eggs were laid down, it should be noted that the initial measurements were made in the water of the hardening tub in which the eggs had stood for about 2 hours. It has been observed that water

Table 1.—Increases in volume of salmon eggs as indicated by periodic remeasurement

Date	Lot 1 (ounces)	Lot 2 (ounces)	Lot 3 (ounces)	Lot 4 (ounces)
December 28	44¼	43¼	43½	44½
January 11	45	45	44½	45½
January 30	46	46	46	46
February 21	46	46	46	46½
March 24	46	46	46	46½

in which eggs have been hardened often shows a slightly syrupy consistency. Such water would be of great density than natural fresh water and eggs would not settle as closely in a vessel containing it as they would in fresh water. For this reason the increase of 9.5 per cent recorded might be considered the actual increase in volume during incubation. In other words, the initial shrinkage would not be expected in eggs hardened in running water.

To confirm the above findings and to determine their validity when applied to Atlantic salmon, a test was carried out at the Saint John Hatchery. The group of eggs used had been spawned and laid down in the hatchery on November 5, 1940. From this group 24 fluid ounces were measured carefully and segregated on November 25. The loss from the 24 ounces up to February 27, when the eggs were well eyed, was 359. On that date the loss was replaced with 359 eggs from the original group and the test lot was re-measured. It was found that the volume had increased from 24 to 26 ounces, a gain of 8.3 per cent.

From February 27 to April 16 a further loss of 109 eggs occurred. On the latter date when the eggs were near the point of hatching, the loss was replaced from the original lot and the test lot was remeasured a second time. It was found that the volume had increased to 26½ ounces, a total increase of 2½ ounces or 10.4 per cent.

In the test of Atlantic salmon eggs, the measurements were made in a cylindrical 8-ounce graduate of not more than 2 inches diameter.

THE PARASITES OF THE FISHES OF LAKE WAKONICHI, CENTRAL NORTHERN QUEBEC

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ABSTRACT

An account is given of the parasites of the fishes of Lake Wakonichi in northern Quebec. Although Lake Wakonichi is unmodified, the extent of parasitization of the fishes, and especially the game species, is equal to that encountered elsewhere in modified waters of the Province of Quebec. In fact, infestation of lake trout by *Cystidicola stigmatura* exceeds that known elsewhere in the Province. *Eubothrium salvelini* was also present as a heavy infestation. *Glaridacris confusus* has been recorded from the headwaters of the St. Maurice River, but was not found by the author in the southern portion of Quebec. Parasitization of the smaller fishes was less than in more southern waters which condition may be correlated with the absence of many species of water birds that do not penetrate into the Lake Wakonichi district.

INTRODUCTION

There exists a tendency to the belief that heavy parasitic infestations of fresh-water game fishes are to be correlated more or less directly with modification in the habitat. The few records herein are based on collections made during a trip to Lake Wakonichi, a headwater lake on the Rupert River system, situated immediately south of Lake Mistassini. The Rupert River drains a small watershed from the central Laurentian highlands of northern Quebec westerly into James Bay.

Lake Wakonichi is well known for the game fishing which it supplies. Situated north of the height of land and 150 miles by air from the railroad, it has been relatively inaccessible until recently and visited ony by voyageurs and trappers passing mainly to the Hudson Bay post at Mistassini. The lake itself shows no evidences of having suffered modification of any kind, the only indication of human interference being an abandoned trading hut at the north end. Other than this, around the shore and for miles back from the lake, natural conditions prevail.

I had the opportunity, while at Oskelaneo waiting to go north, to examine fishes from the Bureau Lakes, the headwaters of the St. Maurice system which is tributary to the St. Lawrence. These records are added below in extension of the range of certain parasites in Quebec. At Oskelaneo, I examined 8 northern pike (*Esox lucius*), 12 whitefish (*Coregonus clupeaformis*), and 4 fallfish (*Leucosomus corporalis*), but obtained no parasites. While at Lake Mistassini, I examined one northern pike, 3 yellow pikeperch (*Stizostedion v. vitreum*), and a total of 13 other species, but I obtained parasites only from lake trout (*Cristivomer namaycush*), brook trout (*Salvelinus fontinalis*) and chub minnows (*Coueusius plumbeus*).

Parasites Obtained

Crepidostomum cooperi Hopkins is a coronate trematode common in the brook trout in the Province of Quebec, and I have obtained it from the Appalachian and Laurentian areas as well as from the Labrador coast, New Brunswick, Nova Scotia and Prince Edward Island. The material of this species taken at Lake Wakonichi was obtained from small brook trout caught in streams entering the lake. The smallest specimen was 0.42 millimeters in length with well developed vitellaria. Other mature specimens were taken, none exceeding 1.5 millimeters in length. The present material is uniform in size and morphology with material from the southern part of the Province, and the extent of the infestation, while not great, quite parallels that found in brook trout from modified waters in the southern part of the Province.

Eubothrium salvelini (Schrank), a cestode, was present as a heavy infestation in 7, and to a lesser extent in 8, of the 20 lake trout which were taken from Lake Wakonichi. It is a common parasite of this fish and of the brook trout in the Province of Quebec, but the extent of the infestation in the fish at Lake Wakonichi was greater and persistently heavier than I have encountered in lake trout in the southern districts. Larval forms commencing strobilization were common and taken from fish having heavy infestations of adult worms.

Proteocephalus larva sp. inq.; were also common in lake trout at Lake Wakonichi. They were generally found associated with *E. salvelini*. The larvae ranged from 1.0 millimeters long by 0.2 millimeters wide to 3.25 millimeters long by 0.5 millimeters wide, and were represented by a simple plerocercus in the majority of specimens, although a few were found in which early traces of strobilization were evident. Four large cup-shaped suckers were mounted on a rectangular scolex.

Glaridacris confusus Hunter.—I was unable to obtain adult common suckers (*Catostomus commersonii*) at either Lake Mistassini or Lake Wakonichi, although it is common in both waters; but of 12 adults taken at Lac à Soudres, Oskelaneo, on the headwaters of the St. Maurice, 5 were lightly infested by this caryophyllid cestode. I have examined many common suckers in the southern part of the Province, and a few from other parts of eastern Canada but these are the only specimens of this cestode which I have obtained so far. The present material was of uniform size, 4.0 millimeters in length by 0.5 millimeters in width and the majority carried eggs.

Cystidicola stigmatura (Leidy), commonly reported elsewhere from lake trout, was present in large numbers in the air-bladder of the specimens taken at Wakonichi. Two hundred to 500 worms were usually present in the air-bladders of fish only 2 to 3 pounds in weight. Others were found encysted in the mesenteries. A single specimen was found in the air-bladder of a brook trout taken from the outlet of Lake Wakonichi. Other brook trout, taken from the inlets to the lake were free of this parasite. A single female nematode differing from *C. stigmatura* only in lacking polar filaments on the eggs was

taken from the small intestine of a chub minnow caught in shallow water at Lake Wakonichi. I find that polar capsules are not evident on early developing eggs of *C. stigmatura* from lake trout and on this basis do not hesitate to refer the specimen from the chub minnow to the present species.

Cystidicoloides hardwoodi (Chandler) was taken as adult males and females from the intestine of several brook trout in an inlet from a small lake about Lake Wakonichi. *C. hardwoodi* is not uncommon in southern Quebec, and to date all my material of this species has come from brook trout living in small streams. I have also a few specimens from New Brunswick. The largest female collected at Lake Wakonichi was only 7.6 millimeters in length.

Echinorhynchus leidyi (Linkins) Van Cleave, an acanthocephalan, is a common parasite of the lake trout in eastern Canada and was present in 9 of the 20 fish taken at Lake Wakonichi. All were present in the rectum of the hosts, which weighed from 2 to 6 pounds. The majority of worms were egg-bearing females.

Pomphorhynchus bulbocolli Linkins.—As previously noted for *G. confusus,* I was unable to collect adult common suckers at Lake Wakonichi, but suckers taken from Lac à Soudres, Oskelaneo, were heavily infested by this acanthocephalan. The worms were nearly all egg-bearing females. It is worthy of note, that less than a month later common suckers from the St. Lawrence River at Montreal yielded only young immature forms of this species.

Discussion

The present collection of parasites from lake trout and brook trout taken from Lake Wakonichi is similar to collections from these fishes from the more southerly, modified waters in the Province of Quebec. It appears, in the writer's experience, that in the majority of cases modification of a body of water does not lead to change in the nature or severity of the parasitic infestations of the game fishes. Parasites may play a significant part in affecting trout populations. The unique example of Lake Edward has been previously recorded (Richardson, 1937) where the nematode, *Philonema agubernaculum,* caused serious internal damage to the trout and interfered with the natural reproduction of the species in that lake.

Generally, parasites do not contribute to the decline of game fish populations following modifications of a body of water. Such a condition results more frequently from damage to natural spawning and feeding areas due to fluctuations in the level of the lake following damming. The possibility of parasites playing a significant role in the decline of the game fish in any particular lake should not be dismissed without examination.

Such distinctions as may be made between the infestations of the fishes in Lake Wakonichi and elsewhere in the Province of Quebec appear more clearly in the small-fish population, than in the game fish.

Heavy infestations with *Clinostomum marginatum*, strigeid metacercariae, and other bird-borne parasites were completely absent from the fishes of Lake Wakonichi, although abundant throughout the southern part of the Province. In this connection, I mention that the only fish-eating bird I observed at Lake Wakonichi was a common tern. The heron, bittern, kingfisher, and similar fish-eating birds are common around the lakes and streams in the Appalachian and Laurentian districts. They apparently do not occur in the vicinity of Lake Wakonichi and were not known to the Indians, or others acquainted with the district.

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CLASSIFICATION OF FISH-CULTURAL PRODUCTS AND METHODS OF DETERMINING THE NUMBERS OF FISH CONTAINED IN INDIVIDUAL ALLOTMENTS

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ABSTRACT

According to published reports and information furnished in response to questionnaires distributed in 1940, there is considerable difference in the age or length of fish listed under the various classifications used by fish-cultural agencies in the United States and Canada. There also is considerable difference in the methods employed to compute the number of fish in individual allotments and to determine seasonal production. The classification "fry" has ten different meanings and the term "advanced fry" six meanings. The classification "fingerlings" refers to ten stages of development. Fingerlings also are classified according to number, length, or age.

The numbers of fry contained in individual allotments are calculated in six different ways and the number of fingerlings by five different methods. Some methods are as accurate as is reasonably possible, while the accuracy of computations based on egg measurements and deductions of observed losses are affected by the extent of the "invisible" losses and the efficiency of the individual making the computations.

INTRODUCTION

Published reports indicate that there is considerable diversity of opinion concerning what is meant by the classifications of fish-cultural products commonly employed by various commissions and departments in reporting on production. Diversity also exists in the methods used to determine the numbers of fish in individual allotments or in total distributions. Early in 1940 a questionnaire together with a letter explaining its purpose was sent to all agencies in the United States and Canada engaged in fish-cultural work. The objectives of the questionnaire were to ascertain: (1) The classifications under which fish-cultural products are distributed. (2) The significance of each classification in terms of age, length, weight, or other measure. (3) The methods used to determine the numbers of eggs or fish of various classifications contained in individual allotments.

A total of 54 questionnaires was submitted and comprehensive replies were received from 24 agencies, less complete replies from 12, and no response from 18. In the following discussion the numbers in parentheses after the various items or statements refer to the number of agencies using that classification or method. The data were compiled from reports and other publications, amplified by information from the questionnaires.

Classification

Fish-cultural products are classified as eggs, eyed eggs, fry, advanced fry, fingerlings, yearlings, 2-year-olds and older fish, legal fish, adults, and spawners. The variation in significance of the various terms indicates the need for standardization of nomenclature.

Egg.—Five replies to this item indicated that the term meant green and eyed eggs (2); eyed eggs (2); and newly fertilized eggs (1).

Fertilized eggs.—No disagreement, refers to eggs immediately after fertilization.

Eyed eggs.—The eye spot is well developed, no disagreement.

Fry.—A total of 30 replies were distributed among 10 different definitions of the term: (a) From hatching until the sac is absorbed (7). (b) From hatching until 1 inch long (7). (c) Newly hatched (6). (d) From hatching until 5 days old (1). (e) From hatching until feeding begins (2). (f) Fish 2 to 3 weeks after sac stage (1). (g) Until 2 months after hatching (1). (h) Until 3 months after hatching (1). (i) From 4 to 40 days after hatching, 1 inch (1). (j) Soon after the sac is absorbed (1). (k) Not defined (2).

Advanced fry.—Ten different replies were distributed among six definitions and two replies did not define the term: (a) Free-swimming with the sac absorbed (2). (b) Fish fed for 3 weeks (1). (c) Fish fed 2 to 4 weeks after sac stage (1). (d) From 5 days after hatching until 1 inch long (1). (e) From sac stage until 1 inch long (2). (f) Fish 1 to 1½ inches long, or 6 to 8 months old (1).

Fingerlings.—Seventeen replies were distributed among 10 different definitions and 4 replies that gave no designation to the term: (a) Fish from 1 inch long to 1 year old (2). (b) Fish from 2 inches long to 1 year old (2). (c) Fish 1 to 6 inches long (2). (d) Fish 1 to 5 inches long which are 5 to 19 months old (1). (e) Fish 2 to 6 inches long which are 5 to 9 months old (1). (f) Fish 2½ to 3 inches long (1). (g) Fish 2½ to 5 inches long (1). (h) Fish 3 to 4 inches long (1). (i) Fish 3 to 5 inches long (1). (j) Fish 4 to 12 months old from hatch (1).

No. 1 fingerlings.—Seven replies were distributed between two definitions and one reply did not define the term: Fish 1 inch long (5); fish fed a short time (1).

No. 1½ fingerlings.—No disagreement for the two replies received stated that the term refers to fish about 1½ inches long.

No. 2 fingerlings.—Nine replies were distributed between two definitions and 1 reply which did not define the term: Fish about 2 inches long (7); fish that have been fed about 2 months (1).

No. 3 fingerlings.—Seven replies included two definitions and one reply that gave no definition: Fish about 3 inches long (5); fish fed until late September (1).

No. 4 fingerlings.—Seven replies included two definitions and one reply that gave no definition: Fish about 4 inches long (5); fish fed until about November (1).

No. 5 fingerlings.—Seven replies included two definitions and one reply that gave no definition: Fish about 5 inches long (5); fish 5 inches long and 1 year old (1).

No. 6 fingerlings.—Five replies included two definitions and one reply that gave no definition: Fish about 6 inches long (3); fish 6 inches long and 1 year old (1).

Fingerlings 1 inch, 2 inches, etc.—According to one definition supported by 3 replies the term means fingerlings of the length indicated by the number in the term; and according to the other definition supported by 1 reply the term refers to fingerlings of the length and age indicated by the numerical designations in the term, for example, 1-inch fingerlings are 1 inch long and of the age indicated.

Fingerlings 1 month, 2 months, etc.—Defined as fingerlings of the ages in months as listed in the reports from one agency.

Yearlings.—Eleven replies were distributed among three definitions and includes three replies in which no definition was given: Fish from 1 to 2 years old (6); fish 1 to 2 years from date spawned (1); and fish over 1 year old (1). The terms "yearlings No. 5" and "yearling No. 6" are used by one agency to refer to fish 1 year old and 5 inches long and fish 1 year old and 6 inches long, respectively.

Two-year olds.—The term is used by five agencies with three different meanings: Fish 2 years old (3); fish 2 years old from the date spawned (1); fish 2 to 2½ years old (1).

Legal or legal-sized fish.—Three different definitions are exemplified by the usage of three agencies: Fish 7 to 9 inches long; fish 6 inches long; fish 7 inches long or longer.

Adults.—Seventeen agencies use the term, 5 without definition, and 12 with 7 different meanings: (a) Mature fish, 2 years old or older (5). (b) Fish 2 years old or older from the date spawned (1). (c) Fish 6 to 8 inches long (1). (d) Fish 1 to 3 years old, 6 inches long or longer (1). (e) Sexually mature and of spawning size (2). (f) Fish 1 year old or older (1). (g) Fish over 2½ years old (1).

Among these miscellaneous terms and their diverse meanings are to be found spawners referred to as "sortings from spawning fields," mature fish defined as "fish 7 inches long or longer"; meanings obviously far from literal or ordinary interpretations of the terms.

Measurement of Products

Below are summarized briefly the methods of computing the products of the hatchery. Some methods undoubtedly are fairly accurate and others are reasonably accurate. Additional methods are little more than an "accurate guess" because they do not include any estimate of the "invisible losses" that occur from various causes and which may amount to between 40 and 60 per cent of the fish reported on the pond or hatchery inventory. (See Griffiths, et al., 1941.)

Eggs.—Seven agencies computed the number on the basis of the contents of a unit measure, and one of them stated that a 6-inch "pig trough" and a measuring chart are used to compute the number of

eggs of different sizes in a liquid quart. One agency estimated the number of eggs from sample counts.

Fry.—Six different methods of determining the number are in use: (a) Estimate based on egg measurement and losses deducted (6). (b) Estimate based on volumetric measurement and sample counts (6). (c) Estimate only (6). (d) Estimate based on weight and sample counts (2). (e) Estimate based on sample counts (2). In one instance a standardized dip net 2 by 10 by 12 inches is used and the average number of fish in each dip-net is multiplied by the total number of dip-nets filled. (f) Estimate based on water displacement (2). The number of fish in a unit of liquid measure, such as a quart or gallon, is determined by count. In one case the water displacement is indicated by graduated marks on a light metal cylinder into which the fish are placed for measurement and are then poured into the distribution cans or containers. In another instance the displacement is indicated by a device consisting of a measuring tube and gauge glass which are attached to the top of the distribution can.

Advanced fry.—Two agencies determined the numbers by estimating the total from sample counts, and three agencies relied on rough estimates only.

Fingerlings.—Numbers are determined by 30 agencies using 5 different methods: (a) Numbers determined by actual count (10). (b) Estimate based on weight and sample counts (10). (c) Estimate based on sample counts (5). (d) Estimate based on water displacement (3). (e) Estimate based on egg measurement, losses deducted (2).

Yearlings and older fish.—Thirteen agencies determined numbers by actual count and 6 agencies estimated numbers on the basis of weight and sample counts.

Pike-perch and whitefish usually are distributed as fry in early stages and distribution figures are based on the measurement of eggs as they are collected, or on a second measurement made when the eggs become eyed. Observed losses in eggs and fry are deducted from the egg measurements and the balance is recorded as planted fish. Fry ordinarily are distributed after the yolk sac is absorbed but sometimes are distributed before that time. Usually eyed eggs and sac fry are distributed to relieve crowding in hatcheries or ponds except where eyed egg planting is the only way whereby remote areas can be seeded.

The foregoing discussion of the connotation of the various terms used in fish-cultural practice and of the methods used to determine the production of fish-cultural establishments demonstrates the need for a critical study of the entire field and for the adoption of standard terms and methods of measurement by all fish-culturists. This field is appropriate for study by a special committee of the American Fisheries Society.

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PART III
PANEL DISCUSSIONS

THE PLACE OF FISH PRODUCTION IN A PROGRAM OF MULTIPLE WATER USE

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THE CHAIRMAN:

Water has always been of prime significance in making the earth habitable, as we quickly appreciate in crossing the arid west. Water use ranks with land use as a factor in human existence and civilization. It supplies us with a considerable proportion of our food and makes possible all food production; if we include soil water in our consideration. On water we transport ourselves and our goods. Through water power developed by damming streams we make use of the energy of the sun, and we will be increasingly dependent on this source of power as we deplete the supplies of coal and oil which have stored the energy of bygone sunlight. Centers of population and of industry have been made possible by the use of water to carry off waste products, and by the storage of water to make it available during seasons or years of drought. In similar ways drainage and storage have made agriculture possible in many regions. Recreational, esthetic and health values of water are each of prime importance, though some members of this Society minimize its health-giving powers.

Multiple water use now exists, but the use is seldom as wise or as efficacious as it should be. Fishery interests in particular have been neglected, and fish experts have often not had, or have not fully taken, the opportunity of representation on planning boards and administrative agencies concerned with water use.

When under control, water, considering its manifold uses, is man's most indispensable friend. When out of control, as in raging floods, excessive drainage, unwise impoundment, gross pollution, water is a destructive scourge.

We were asked in these panel discussions to adhere more or less to the American Fish Policy. Before the discussion opens I will read two sections of the policy which pertain to multiple water use. Section II (1) reads:

"The federal, dominion, state, provincial, and regional planning boards should consider the fishery resources as a very important element of national wealth and not as a minor incident in the development of power, flood control, drainage, irrigation, reclamation, and recreational projects, as has been done in the past. The planning boards should recognize wherever possible the principle of prior right for the fisheries. Only when a proposed water development exceeds in public value the fisheries resource, should the latter be sacrificed, in which case the fishery interests should be compensated fully for their losses. The fisheries should be given equality of representation on all planning agencies at all times and should be represented by qualified persons from the state, provincial, and federal agencies involved."

Note that it says "state, provincial and federal." One other section is significant in our present discussion:

"Since soil erosion, reforestation, drainage, flood control, water restoration, and impoundment of waters are now recognized as tremendously important factors in fish production, the closest contact should be maintained between fishery officials and the agencies responsible for these various activities."

I have tried to outline this topic in such a way as to give a fairly rounded discussion of a very large subject. I am going to ask several persons in the audience to present informal remarks, avoiding detail, so we may have the benefit of their knowledge and experience as they bear upon this problem of multiple water use.

DR. SHANTZ:

The Forest Service is tremendously interested in the waters of the National forest areas, since we are held responsible by Congress for the management of the forest lands. Our responsibility is very great in respect to the waters and lakes fed by those lands. No doubt the richness of a body of water is largely measured in terms of richness of the lands which feed them. To that extent anything that is done in the management of forest lands is reflected at once in the charcter of the waters which drain those areas.

We are anxious above all to see the waters of the lakes and streams made a productive part of our National resource. To that end we have worked with the State game and fish departments and with the Fish and Wildlife Service to increase the productivity of these waters and keep them in as good condition as possible. The work with the States has depended largely on what the State wished us to do. Wherever they wished us to help we have tried to do so, and wherever they felt they could better do the job themselves we have had little choice other than to allow them to do it. However, there are two or three problems in which we are very definitely interested. In the national forests there are uses for our waters. There are reservoirs which of necessity fluctuate in level. There are irrigation reservoirs that likewise are subject to great fluctuations. In some places we have been able to go back into the upper reaches of these great reser-

voirs and to establish permanent level areas by constructing small dams, in order to improve not only the conditions for fish but the conditions for wildlife in general. We have also worked closely with the Federal Power Commission in order to prevent power developments from closing up streams. For some reason or other the last drop of water is more valuable than the first, and there is a tendency in damming rivers not to allow sufficient spill and the cost of keeping the streams alive is difficult to justify because of the high value of the water when measured in terms of electric power.

There are many areas far in the back country where fishing and even stocking is difficult. In most of these areas we have been able to aid the State departments by carrying stock for these lakes and streams. Of every 100 people who visit the forests, 20 come for fishing and 8 for hunting. Four and a half million people came to the forests last year for these purposes.

It is evident also that we have tremendous problems which touch upon the problems of fertilization now being studied by Swingle and Smith of Alabama. The Forest Service has jurisdiction of many large parcels of land which were not specially suited for other purposes. In these areas there is a population of dependent people, so that we have inherited an immense social and economic responsibility. There are great areas where the production of food in small ponds and lakes is a vital necessity. Many people in those areas are undernourished and cannot easily produce sufficient food by raising domestic animals. We feel that there is an opportunity to do something for thousands of people who otherwise would continue with a thoroughly unbalanced diet, by increasing the fish production of ponds and the production of game on these forest areas.

MR. DARLING:

You will be glad to know that I am under doctor's orders to make no speeches. I look all right on the outside but I have a lot of crutches on the inside.

I know of no more important subject in the United States today than the multiple use of waters. There is a great battle to fight. I am here as a listener. I am out of the picture temporarily, but I am glad to be here and to see again so many of my old friends.

DR. WIEBE:

I believe we fishery workers and conservationists must realize that we face a period in which there will be considerable hydro-electric development. What is going to be our position? Are we going to say that there should not be any, or are we going to accept the program in the main, try to keep it under control, and make the best of it? The reservoirs created by the Tennessee Valley Authority are ex-

tremely popular within the region in which they are located. I am satisfied that if a poll were taken today or any other day as to whether we should retain the reservoirs or should go back to the original Tennessee River—some people have said we have ruined the Tennessee River—the vote would be overwhelmingly in favor of retaining the reservoir.

It is estimated that the recreational business associated with the Norris Reservoir is in the neighborhood of a million and a quarter dollars per year. Formerly there was a very small river, with a flow of 300-500 second-feet. Now we have a reservoir with a capacity of 32,000 acres; it is all nice clear water, and people can have a lot of fun and see a lot of pretty scenery. If you should visit and see all the automobiles from Kentucky, Ohio, Michigan and Minnesota, where many natural lakes occur, you would appreciate that a little more.

The water-use program of the Tennessee Valley Authority has two distinct phases. One is to retain the water on the land. For that reason the Authority is engaged in an extensive program of fire control, soil-erosion control, and reforestation. I am convinced that we are engaged in the best stream improvement work in the country. If we can regulate the run-off, stream flows will be more constant and there will be a more favorable environment for fish.

The Tennessee Valley Authority Act (16 U. S. C. 831) states certain objectives specifically. Fish and game are not mentioned. The objectives are: Flood control, navigation, power production and National defense. While fish and game are not mentioned specifically, by implication in Section 22 of the act, fishery and wildlife work, agricultural improvement, forestry and other related activities are permissible.

Flood control, then, is the first objective. That is something people will not quarrel over. We are in favor of flood control, and in that regard it should be emphasized that flood control and navigation have prior rights over power production in the use of water. This priority is borne out by the fact that when the storage reservoir gets low but still contains considerable water, steam plants are set up to generate power, and the impounded water is routed through to maintain a navigable channel. Again, in times of incipient floods, the reservoirs are lowered in anticipation of the floods. Such is the priority that flood control and navigation have over power production.

With regard to the fishery work in the multiple-use program, as I have said, it is not stated specifically in the act as an objective of the Authority. Those of us who are engaged in fishery work are in a somewhat peculiar position; we represent a tiny appendage on an enormous organism or animal. Therefore our problem has not only been the fisheries but also to sell the fishery problem to the Authority. There is scarcely an engineer in the Authority who does not respect the fishery workers and their program. Our work has shown that, although the primary objectives are flood control, navigation, power

and national defense, we can develop very excellent fishing. Over a million fishing trips occurred on our four reservoirs in Alabama last summer and more than a million pounds of fish were taken by commercial fishermen. Three and one-half million pounds of fish were taken by sport fishermen.

There is no indication that these reservoirs eventually will become barren. The Wilson Reservoir, which is 16 years old, supports fishing as good as the reservoirs that are 2 to 5 years old; in fact better. It is of extreme significance to good fishing that the fish have a chance to be born. During the spawning season we ask the Water-Control Board to stabilize water levels, and they do it, on the large reservoirs. Some of the smaller units are so small and have so much head that stabilization is not easily achieved.

Good fishing can be had even if the water is used to generate electricity. Power generation doesn't seem to make much difference to the fish. We are fortunate in one respect; we do not have much pollution. In fact, sometimes I wish we had a couple of good sized cities on Norris Reservoir to contribute some fertilizer. In this program of hydro-electric development involving a single reservoir and a certain community depending on it for power, that reservoir is going to fluctuate no matter how many resolutions this meeting may pass urging a contrary policy. When an entire river system is harnessed as we are doing at the Tennessee River, and where a series of reservoirs is established, the water runs from one reservoir into another. Unless the load is unusually heavy, power is generated here today and there tomorrow. Properly developed and properly regulated I believe that multiple use of the water, even if largely due to the necessities of power, can still produce a great deal of fishing. People don't have to believe a word I am saying—come down and see for yourselves; you are welcome!

MR. HIGGINS:

Dr. Wiebe has referred to the fortunate circumstances which have produced excellent fishing in the Tennessee Valley and has demonstrated clearly the advantages that have resulted from the program of multiple use of water in that area. We have quite a different problem in the Pacific Northwest where anadromous fishes are concerned. Dams can be of no benefit whatever to anadromous fishes because their spawning grounds are often above the obstructions and the production of fish life within the reservoirs is relatively unimportant. I can describe to you briefly four or five situations in the Pacific Northwest which, arranged in chronological order, indicate a trend which I regard as one of the fortunate circumstances among the many unfortunate ones involved.

You all know something of the history of the Bonneville Dam on the

Columbia River—at that time one of the greatest engineering achievements and one that obstructed the largest run of anadromous fishes. The money was provided and the Corps of Engineers of the U. S. Army began their plans for construction long before there was any thought of protecting the fishery resources. Before construction began, however, and through the insistence of fishery interests, the former Bureau of Fisheries was called into the picture and one of our biologists was detailed to begin a study of the protection of the fish of the Columbia River.

Construction was to begin within less than a year of the time the surveys and studies were undertaken, consequently there was insufficient time for a complete solution of the problems of fish protection. Starting from scratch, Mr. Harlan B. Holmes, our biologist, and Mr. Henry F. Blood, the engineer from Portland, Oregon, devised between them a general program of fish-ladder construction to provide access to the upper spawning grounds of the Columbia River. The devices involved all the good practices in fish-ladder construction as then known, and a number of novel devices were used which have proved themselves to be very effective. The Army engineering staff, of course, contributed very largely to the detailed designs. Before any amount of concrete was poured provision was made in the foundation of the dam for a series of four large ladders 40 feet wide. Two sets of duplicate fish locks or so-called elevators were provided also.

That effort, carried through in such haste, has produced satisfactory results so far as up-stream migration is concerned. The runs of salmon have passed the Bonneville Dam with no interference whatever. There has been no accumulation of fish below the dam; once they enter the fishways they pass over very rapidly. One fortunate circumstance is that counting weirs were established in the heads of each of these passages and we now for the first time are able to keep books on the salmon resources of the Columbia River, knowing as we do the escapement past the greater part of the commercial fishery to the spawning ground.

The next major problem encountered was concerned with the construction of the Grand Coulee Dam. There again the dam was authorized and the money provided long before studies of fish protection were undertaken. Before the U. S. Bureau of Reclamation began its construction program, money was allotted to enable fishery biologists to make preliminary surveys, this time for a period of a year, and a considerable amount of valuable information regarding the protection problem was amassed.

The Bureau of Reclamation was very sympathetic to the problem of fish protection. They provided a liberal fund for the continuation, for a period of perhaps 8 years, of a system of transference of the main runs of salmon obstructed by the Grand Coulee Dam to major tributaries below, between the Grand Coulee Dam and the Rock Island Dam, where the fish could be caught on their upstream migra-

tion. There is now in progress an elaborate program of transference, catching the upstream migrants, hauling them in "air-conditioned trucks," as the newspaper men like to call them, and depositing them either in favorable spawning streams below the Grand Coulee Dam or transferring them to the hatchery at Leavenworth, Washington, where the usual fish-cultural practices are followed. That program, with all its difficulties of handling great numbers of very large fish in rather shallow and fairly warm water, with attendant disease, which is a headache to the fish-culturist, is developing in a promising way.

Next we have a program of water development in the Central Valley of California. Already under construction and well on toward completion is the Shasta Dam on the Sacramento River, which will prevent the access of considerable runs of salmon to their major spawning grounds. Here we were less fortunate in finding the right solution, such as the transference of the runs to new spawning areas, because the Central Valley is so arid and the streams so intermittent and so small that adequate spawning grounds in tributaries below the dam simply do not exist. The only hope, therefore, of maintaining that considerable run will be an elaborate system of artificial propagation to supplement whatever natural spawning is still possible.

Below the Shasta Dam three racks will be placed in the main Sacramento River, where the spring run of salmon as it approaches the dam, will be divided into groups and where we believe there will be a considerable amount of natural spawning. The remainder of the spring run and most of the fall run will have to be transferred by truck, by much the same process as is used in the Grand Coulee program, to hatcheries, or placed in one of the two tributaries below the dam that have enough water to support them. I must admit frankly that the prospects of maintaining that considerable run of salmon are far less bright than they are in the case of the Grand Coulee salvage program.

The construction of the Shasta Dam also is being undertaken by the U. S. Bureau of Reclamation. In the early stages money was provided for extensive fishing surveys which have been under way now for nearly 3 years. Further studies will be carried on for the next several years in relation to the problems of the other parts of the Central Valley program, particularly the protection of the fish from the pumping plant which will be established on the lower Sacramento River to supply water to the lower San Joaquin River. A cross channel will be built to satisfy the demands of irrigation in the lower San Joaquin River. These problems are still to be faced, but the Bureau of Reclamation has shown, as I have said before, a very sympathetic attitude and is providing money.

We still have before us the problem of flood control on the Willamette River, which is perhaps the worst headache of all, because below the four large dams still to be built there are so few tributaries or spawning areas that can be made available to the fish that in all likelihood the Willamette salmon run can be continued only through artifi-

cial propagation. The War Department, which is responsible for the development, is providing funds for surveys and further studies.

In another field the Bureau of Reclamation has shown an increasing interest in fish protection, namely in the screening of irrigation ditches. Starting some 7 or 8 years ago, P. W. A. funds were provided the Fish and Wildlife Service to enable it to construct a number of very large screens in major Federal irrigation projects. A rotary screen has been developed to a very satisfactory state of perfection. Five very large screens are operating in canals that are big enough to float a steamship. The screens are perhaps doing more for the protection of the salmon runs in the Columbia River Basin than any other single thing I can think of, because in the unscreened ditches tremendous quantities of downstream migrants went to their death.

A fortunate trend in all these cases is the growth of appreciation of fishery problems on the part of other public and Federal agencies. At Bonneville Dam, as I have said, construction was about to begin before problems affecting the fisheries were considered. In these other cases conservation of the fish supply has been given every consideration, and earlier consideration than in the previous project. Finally, there is the recognition by the Bureau of Reclamation of the priority of fish rights, even priority over irrigation, which is rated so high, by building from their own funds, on their own initiative, and with their own engineering talent, a very large fish screen in the Rosa diversion on the Yakima River, the last large reclamation project that has been completed. That screen comes into operation this year and undoubtedly will prove very effective.

With this growth of interest, then, on the part of Federal construction agencies in the conservation program I believe we are making progress; I believe that the problems of multiple water use will be solved and that the entire program of full utilization of our resources will be facilitated.

THE CHAIRMAN:

I know of another gentleman who would have enjoyed the opportunity to speak on our topic of the multiple use of water, but he is unable to be here. I wish to quote two paragraphs from his letter, however, in which Mr. William L. Finley expresses his views:

> "The fish resources of the Northwest are very valuable, but not properly protected because of the lack of necessary laws. The spring chinook salmon are of the greatest importance but have been going down steadily for many years in the Columbia River. The laws of Washington are more protective than the Oregon laws. The demand for more dams on the Columbia and Willamette Rivers is destructive, but the promoters claim the salmon will be maintained by artificial propagation, which is not scientifically correct.
>
> "At present there is a flood-control bill in Congress which may be passed before your meeting is held, allotting more money for these high Willamette dams. It seems to me that the American Fisheries Society should fight for fish protection."

MR. REID:

I heartily concur in the views Mr. Finley has expressed in his letter. The problem of proper protection for the fisheries from the tremendous hazards imposed by power, irrigation, and navigation developments is difficult to solve. The fisheries commonly have received only the "hindmost." It is encouraging to hear of the progress reported in this field by Mr. Higgins, and I know that some improvements have been made. But we still have to face the unpleasant fact that in large construction programs, if the fisheries receive any consideration, it is largely a gesture. Not only the fisheries suffer but the broad public rights in water, including the right of American citizens to enjoy our aquatic resources, receive little consideration. Inalienable public rights are subordinated to the special-interest uses of public waters. We may as well face the facts now.

I was greatly interested in Dr. Wiebe's comments on the T. V. A. program. I had the pleasure of spending a day with him and some of his colleagues last year and saw some of the reservoirs. When we consider the place of the fisheries in programs involving the multiple use of water, much depends on where the dams are constructed. Did the river blockaded by these dams have more aquatic values to begin with or did the dams provide better possibilities for productive fisheries? In the case of the Tennessee River, it was comparatively low in productivity. In sport fishing I believe the dams on the T. V. A. are, as Dr. Wiebe has said, on the asset side of the ledger. A more specific case is Boulder Dam on the Colorado River. It was a river too thin to plow and to thick to drink, a river that was practically worthless from standpoint of aquatic life and recreation. Boulder Dam has created more fishing on the upstream side of the dam for black bass and on the downstream side for rainbow trout. I had the pleasure of fishing both during the 2 days I was there last December. I wish to point out to you that the fishing at Boulder Dam, both above the dam and below, was merely a happenstance. If the Colorado River had been a good fishing stream and the dams, having regard to the purposes for which they were built, ruined it, it would have been ruined without the batting of an eye.

Let me give you another example. The Gunnison River in Colorado was a famous trout stream. I fished it for 20 years, off and on. A dam had been built by the Bureau of Reclamation on the Taylor River, one of the head forks of the Gunnison, to supply water users far down the Gunnison Valley. When I was there in late June the river appeared as if it were at the mid-August stage. The reason was that the spillways in the dam had been closed to store up water for irrigation. Then I went on an inspection trip for 5 days and came back at the end of the week of July 4. The river was high and dirtv. During the week of July 4 the river was lined with fishermen, the whole way up the Gunnison, and I am sure I saw at least two or three hundred fishermen and not a tight line. On the opening day six boys

had come to the hotel to spend a week fishing. A day and a half later they left in disgust because of the utter disregard for anything except so many acre-feet of water for irrigation. The water users association had called for water, and up went the gates of the Taylor Dam. For many people who visited the river for their only vacation the fishing was ruined and they went away disgusted. That is not good water management; it is not management in the public interest. It is that sort of narrow-minded, selfish, inconsiderate water management that we have to get changed.

That undesirable condition could have been corrected; it need not have happened. Of all the weeks in the whole 52 of the year to run sulky water down an outstanding trout river, the week of July 4 was obviously the worst. Furthermore it could have been done gradually if any had to go down that week. But it was not done, simply because there was no consideration for fishing. The proper point of view in connection with these water problems is consideration of all values, not just consideration of one or two or three utilitarian uses that involve private exploitation of water, whether done with Federal money or with private funds. It is a problem simply of social behaviour. Consideration of the rights of others will solve 90 per cent of these problems.

I made it my business a few years ago to find out why hydro-electric power and reclamation always got the ringside seat on these water developments, and why not only the fisheries but the whole interest of the public in the use and enjoyment of water were shoved aside. I found out that the reclamation lobby had been sufficiently powerful to get written into the Reclamation Act a provision declaring reclamation to be a priority use of the water, taking precedence over the use of the water by the public. The same applies to hydro-power development through the Geological Survey and the Federal Power Commission. There is something for us all to think about—an amendment to the Reclamation Act which gives preferential rights to hydro-electric power development over public uses of water. We have not attempted it this year, for reasons which are obvious to all of you; nevertheless there is the basic difficulty in this whole water use program.

I was glad to hear from Mr. Higgins that the Bureau of Reclamation is becoming more considerate in this matter. No doubt he is correct, but the Lord knows there is room for much improvement. The Fish and Wildlife Service and the Reclamation Service are brothers and sisters in the same department and naturally they have to be careful what they say about each other. I was in Washington about a year ago trying to dig into this thing and I saw Secretary Ickes. He suggested that I see Commissioner Page, which I did. I presented the problem of screening of irrigation ditches and the necessity for doing something about it at the source. His reply to me was about like this: Most of the western States, practically all of them

in fact, have laws requiring the screening of irrigation ditches but they do not enforce them against the rangers, therefore why should we bother? He said: "I don't believe that we could get our water users who pay for these dams"—and I made a mental reservation as to whether or not they actually do pay for them—"to go to the additional expense of putting in screens." I said: "My God, man, if Uncle Sam's Federal bureaus cannot set the example on this thing, how in the world can you expect any improvement elsewhere?" In other words, I put it squarely up to the Bureau of Reclamation that we believed it was their responsibility to provide these screens in connection with every dam—to provide for their construction and their continuous operation as an integral part of the engineering plans and as a condition of approval of any dam project. Although we have taken our stand on that sort of thing and keep reiterating it all the time, we still continue to get the hindmost.

Then there is the question of flood control. Control of floods is excellent, if it is honest, but I want to say frankly that about 90 per cent of the so-called flood control is a blind for hydro power, for irrigation, for spending large sums of Federal money in a community for political purposes. If anybody wants to argue with me about that, I will be delighted. We might well quit "pulling our punches" and get down to "brass tacks" on this thing. I heard Glen Egerton at a conference in Wilson, West Virginia, make a statement which gave me a better opinion of at least some Army engineers than I had before. As I recall his statement, it was this: "When we are honest with ourselves and get down to the bottom of this flood problem, about 90 per cent of flood damage is the result of man's damn foolishness in building roads, railroads, houses, factories, and what not, on land that plainly belongs to the river. When the evidence that the river had used that land for flood purposes is plainly visible, you can be darned sure the river will again flood that land. It would be much more sensible and economical to retire from human occupancy and use of many of our perennially flooded lands and give them back to the river for flood purposes." I wish some of the Army engineers would have the courage to get up on their hind feet and enunciate such a sound principle.

I wish I had time to go into this flood control business thoroughly. It is certainly being used as a blind and subterfuge for all sorts of "skulduggery". It is being put in as a measure of National Defense. I am getting so allergic to that National Defense argument that comes up in every bill in Congress.

In considering this problem of multiple water use, the important thing is to bring in biologists and scientists at the outset and not for a post mortem as in the past. The "Coordination Act" of 1934[1] provides for calling in the former Bureau of Fisheries and the former Bureau of Biological Survey, now the Fish and Wildlife Service, and con-

[1]Act of March 10, 1934, 48 Stat. 401-402; 16 U.S.C. 661-666.

sulting them in advance. But that is not quite strong enough. The other more favored agencies have ignored the fish and wildlife aspects of the projects. They have made their plans, begun construction, and then if they felt like it they would tell the Fish and Wildlife Service what was going on. Let me say that these remarks are not intended to criticize the Fish and Wildlife Service or the Forest Service, but I do have some criticism of some of the other bureaus.

What do we have in the way of pending legislation at the present time? One can do no more on an occasion such as this than cover the high points of the legislation that is now before Congress. Practically every one of the bills is called "National Defense"; and many have no more valid connection with National Defense than with any silly project you could imagine. It is almost sabotaging the National Defense program to divert tremendous amounts of money, manpower and material into engineering works that ought to go into the production of planes, guns, and ammunition. The pending flood control bill (H.R. 4911) is another pork-barrel measure. It is an excuse for spending $275,000,000, which, converted into modern fighting planes and dive bombers would give us a fleet of 3,809. Then there is the flood control bill to establish an Arkansas Valley Authority patterned after the T.V.A. In the Ozarks are splendid smallmouth black bass streams that will become carp and buffalo streams after these dams go in. I am going down there before this hydromania gets into operation in order to have something to remember in my old age. This country is tending toward a land in which every rapid and fall will be converted into a gigantic concrete structure for generating hydro power and for so-called flood control.

Representative Rankin of Mississippi introduced a bill in Congress on August 11, seeking to divide the whole of the United States into so-called conservation authorities. It includes the A.V.A., the T.V.A. and six others. Such a bill, if the motive back of it were sound from the standpoint of conservation of natural resources, might conceivably be a good thing, but it is very obvious that this bill is motivated by the same old thing—some people in Washington call it public water conservation, but we believe it to be the rankest sort of political water exploitation. In other words, the purposes of the Rankin Bill are hydro power, flood control, navigation and irrigation; and incidentally, the bill states that among the duties of the so-called conservation authorities shall be the encouragement of the widest possible use of hydro-electric energy and the fullest development of our water resources and the encouragement of the widest possible regulation of our public lands by both irrigation and drainage. Think that over; they call it conservation! The Rankin Bill is called a National Defense measure, in spite of the fact that it will be 5 to 7 years before many of the dams will be completed.

What of the future? I had great hopes for the National Resources Planning Board. A reading of the preamble to their voluminous

report and recommendations made me feel good; it sounded well—it could not have been better if I had written it myself. However, I understand that some of the Federal agencies that appreciate the value of our natural resources have spent hours, days and weeks of work getting out reports and recommendations which apparently have gone into the waste-paper basket. I want to give you just a few of the high points of that report and its recommendations.

Here are a few highlights of the recommendation for outright appropriations for Federal construction projects. For the Army engineers—and not for defense purposes—for inland water navigation, $1,690,000,000. For the Bureau of Reclamation, $1,230,000,000. For the Fish and Wildlife Service, $1,230,000, which is exactly one-thousandth of the amount recommended for the Bureau of Reclamation and one fifteen-hundredth of the amount recommended for the Army engineers. Then we come to the Soil Conservation Service, and we might expect it would be on top. No, only $441,000 is recommended for the Soil Conservation Service, which is one-third of that recommended for the Fish and Wildlife Service and one three-thousandth of that recommended for the Bureau of Reclamation. I see Dr. Shantz is writing some notes; let me tell him something about the Forest Service. At first glance the Forest Service appropriation looks like $842,000,000. It is in three categories: (1) Forest highways, (2) forest development, roads and trails, and (3) wildlife conservation. The first two categories are to be allotted $841,500,000 of the $842,000,000 recommended for the Forest Service.

I sincerely believe that the most serious conservation problem before the American Fisheries Society and the American public is this, that the disease of hydromania that your Government has apparently contracted from the power companies in its more virulent form, blinds the victim to all values in the running stream except so many kilowatt-hours going to waste. You and I see other values in a stream, but not the fellow who is afflicted with hydromania.

Lest anyone here have the conception that I have any concern about who shall generate hydro power and that I am in any way fighting for private interests, it is a matter of record and can be verified by people from West Virginia that in 1930 I was the sole protestant when I wrote the Izaak Walton League protesting against damage to some of my favorite trout streams in West Virginia. Eighty-six miles of them were dried up by the application of the West Virginia Power Company, whose president is a cousin of mine. I hold no brief for the private power company, which is one of the worst disturbers of aquatic values, and it is small consolation to me and to you if it is Uncle Sam instead of a private corporation that ruins your river and my river. All we need for a solution of this thing, as I said before, is consideration of all values in advance of the engineering, and practice of that simple rule of good social behavior—consideration of the rights of others.

MR. WIRE:

If Kenneth Reid had not given us as good a talk as he did, I do not know that I would have dared to get up here, because I would have said something I should not have said. My friend Bill Finley, if he were here, would probably say in a much more vociferous manner what I wish to say.

I do not want anybody to consider my remarks as derogatory of the Fish and Wildlife Service nor of the work of the former Bureau of Fisheries. They were told: "Here is a dam; now you fellows do the best you can with it." When the construction of the Bonneville Dam was undertaken, a certain major of the Army engineers came out there and very inadvisedly made the remark that he was sent there to build a dam and "to hell with the fishing". He was removed very soon after he made that remark, because he found it was very unpopular in Oregon and Washington as well as in other places in the United States. The Fish and Wildlife Service through its biologist and engineer Harlan B. Holmes, got busy and we went through that fight. Fish ladders were put over Bonneville Dam to permit passage of the run of anadromous fish. I cannot say that for the Grand Coulee Dam. Mr. Higgins expressed the difficulty mildly when he said it was a headache. I predict that the ten-million dollar salmon industry on the Columbia River is going to be definitely affected in the cycles to come.

These dams are already built, but we have the Willamette Valley Project that Mr. Reid and Mr. Higgins told you about. A dam 325 feet high is contemplated on the Santiam, one of the tributaries of the Willamette River. The Willamette River is the only important tributary of the Columbia River below Bonneville Dam where there is a valuable run of anadromous fish. The large run of spring chinook salmon, which is the most valuable run in the Columbia River, spawn in the Willamette River and its tributaries. The Willamette Valley flood-control project is the bunk! It is not needed for flood control. If a sum of about $10,000,000 had been appropriated for a revetment or dike along the Willamette River the problem would have been solved; but no, they want to build the dams. In the Willamette Valley we don't need irrigation, we don't need flood control, we don't need navigation.

Another high dam is projected on the McKenzie River, one of the finest streams for anadromous fishes and the spring chinook salmon in the entire water system. The dams will all be too high for any fish ladders, and the only way runs can be maintained, as you have been told, is through artificial propagation. We believe in artificial propagation, but we believe it is only a means to an end. We are also very strong in our ideas regarding natural propagation. Many of the dams will be so far downstream that the spring run of chinook salmon will reach them in June or July. If the fish are held below the dams and the water temperatures increase in the summer, many of the fish will

die before they reach the spawning stage. Production of young will be a failure.

I wish that a resolution could be passed by this Society opposing the Willamette Valley Project. The high dams have not been built, only one or two low dams that do not affect the runs of anadromous fish and which we did not particularly oppose. We do not want these dams. As I told you before, there is not a single excuse for building them except the spending of Federal funds.

MR. SIMON:

I will give you a few examples of our use of irrigation reservoirs in Wyoming and also the stock-watering reservoirs in the State. Our use of such bodies of water is typical of the use given them by other inland western States.

There are four types of reservoirs: (1) The irrigation reservoir or the storage reservoir; (2) the control or regulatory reservoir; (3) the stock-watering reservoir, of which a few hundred have been built in the past few years; and (4) the power reservoir, which is used in combination with the irrigation reservoir.

One of our most difficult problems is in the use of any irrigation reservoir for sport-fishing purposes. We know that the loss of fish due to irrigation greatly exceeds the catch each year by fishermen. We feel that in the planning and construction of these reservoirs aquatic values have been ignored in almost every instance. For example, a new reservoir completed this summer was supplied with water from the Grey Bull River. As the water was let out of the reservoir, for a considerable distance it cut through a clay bank. Whether or not the reservoir meant anything as a fishing locality, the fact that hundreds of tons of silt were washed into the Grey Bull River over a distance of 30 miles makes its value negative to those of us who look upon the river as potentially of greater value than the reservoir itself.

Another difficulty we face constantly is the fact that applications for fish continue to flow in in enormous numbers; applications for reservoirs that we are satisfied are not suitable for fish. It becomes the duty of the State administrators to refuse fish to the public under those circumstances, but these fish have been offered by the Federal agency which raised them. This difficulty could be overcome if the system of application for distribution of Federal fish were dispensed with. Administrators know that it is a difficult thing to have to refuse fish, particularly when the people think they have the fish coming to them simply because they have the water, although they know nothing about its biological value.

We are attempting to screen irrigation ditches on a small scale. With 5,000 reservoirs in the State and an equal number of head gates diverting water out of trout streams the problem is enormous for a State. Legislation passed at the last session of the Wyoming legisla-

ture gave to our department the responsibility for the installation of fish screens, simply because it was the only way we could insure screening of irrigation ditches.

In considering the biological values of reservoirs and irrigation works as a whole, let me point out ways in which there is a loss of fish through irrigation works. One is due to inadequate control of the water as it leaves the reservoir. Another concerns the head gates at reservoirs, or on streams below the reservoirs, or on streams that have no reservoirs on them, in all of which the danger arises through the complete drawdown of irrigation reservoirs containing fish. We have not stocked these reservoirs in which there is a complete drawdown, but since most of them are situated on live streams there is a constant drift of fish into each reservoir, and when the need for irrigation water is great there is no compunction whatever about draining that particular body of water completely. This procedure results in enormous losses of fish.

We have two types of stock-water reservoirs, the live one, and the temporary one. Most of our stream survey work in the last 2 years has been on reservoirs of both types. First we tried to select from the great number of irrigation reservoirs and stock-water reservoirs those which can justifiably be stocked with fish. The live stock-water reservoirs are sometimes good, particularly when they are located below the permanent spring stream run. The temporary live stock reservoirs, however, cannot be stocked because they may be full for 1 or 2 years, but in dry seasons they will be drained before the fish with which they are stocked can be utilized.

Many of the irrigation reservoirs in Wyoming are modified permanent lakes from which only a certain amount of water can be drained off the top. When the old lake on which the reservoir was built was deep enough, many are excellent for fish rearing, and some support excellent fishing today. In the reservoirs which can be drained we dare not plant fish. Agencies responsible for construction of reservoirs are prone to allay the public mind by promising good fishing wherever they create a body of water. That has resulted in ill-feeling on the part of people who see a body of water and expect to have fishing from it. When the State will not or cannot supply fishing the public become critical and our position is difficult, to say the least.

THE CHAIRMAN:

I wish we had time to call on Mr. Bode of Missouri and Mr. Warfel of New Hampshire to express their views concerning this conflict of interests, particularly in connection with the construction of dams. There are many other aspects of multiple water use but in this brief program we have not had an opportunity to discuss them. I do not want to have any of you feel that the problem is narrow. I will briefly

mention a few of these other points with respect to multiple water use before I call on one more speaker for the morning.

We have a very important problem of fish production in recreational lakes—lakes produced for fishing, boating and swimming. Mr. E. B. Speaker could tell us about those constructed in Iowa. Mr. A. R. Shields has already discussed that topic for Tennessee in another panel discussion. We would like to hear from Illinois, where these recreational lakes are being constructed.

I agree with Dr. R. W. Eschmeyer in his statement that the greatest fish increase that we can obtain is through increase in the acreage of water in lakes that are properly managed for fish production. I wish we had an opportunity to go into the question of fish production on farm fish ponds of various sorts. Dr. H. S. Swingle discussed this subject in another panel at this meeting. I will not ask him to repeat his remarks, for I am sure you remember what he said and will include that in the concept of multiple water use. The Soil Conservation Service, as he mentioned, is considering the possibility of fish production in the small multiple-control dams.

Conflicts of interest have been mentioned. There is the question of pollution; Dr. H. J. Deason was to give his views on that, but there is not time. Reference has been made by Dr. Clarence Tarzwell to mosquito-control activities and to a cooperative investigation made in this regard with the Tennessee Valley Authority. We should also hear something of the agricultural use and misuse of water in relation to erosion and silting, a most important cause of depletion of our fishes.

MR. ALDRICH:

Some few years ago we gave a report of a specific instance of the multiple use of reservoirs, particularly for municipal water supplies. In most of the Middlewest, particularly through Oklahoma, the reservoirs are used for municipal water supplies.

Perhaps the first important thing in connection with these municipal water supplies is the fact that we have a State law in Oklahoma which provides that all funds collected on these municipal lakes or reservoirs shall be used for fish propagation or protection. The law also provides that the municipalities may make their own regulations pertaining to fishing on the reservoirs. That is very fortunate. Of course the city cannot increase the State bag limit but it may further restrict the State regulations. The city cannot override the State law, but our laws are quite generous so that it is usually a matter of further restriction rather than of liberalization.

I wish we could practice fertilization in many of the reservoirs, but of course we have to work in cooperation with the State health department and we cannot recommend fertilization of waters in the municipal reservoirs when the waters are chlorinated and filtered. The problem of municipal lakes in Oklahoma consists of making a survey

to determine the existing conditions and then to conduct an inquiry relative to each lake in order to assure the fullest use of the water under the conditions for which it exists. At Tulsa we have never found any correlation between the intensity of fishing and the *B. Coli* count of our municipal waters, which never have suffered any noticeable pollution. We believe that when the regulations are properly designed and people respect the privilege of using these lakes for angling and other recreational uses they enjoy greater benefits than if they were allowed promiscuously to use the stream and ignore sanitation.

We have found that it is most important to give assistance to anglers. By and large, the majority of the fishermen do not know how and where or what to fish for when they enter one of these municipal areas. The surveys should be sufficiently detailed on each one of the reservoir lakes to provide information desired by the anglers. Guides, who actually know the lakes, what to fish, what bait to use, and what particular spot to fish in, are available. We have prepared booklets of different kinds, and we have an aerial map of the lake showing the various fishing holes. We even go so far as to stop and visit anglers who are not familiar with the lake and tell them where to go. We give all these services to the anglers, and that is made possible throughout many of these municipal reservoirs in Oklahoma because all the funds collected on these reservoirs must go into this kind of work. I think at least all the larger municipal lakes do have quite substantial funds for carrying on experimental work, and these funds cannot be used or diverted to any other purpose. Practically all the lakes have experienced managers or custodians. Many are trained men who have nothing to do except study the specific needs of that particular reservoir. I understand that the same practice is followed in a great many other places. The important thing is that we draw the line where fishing would interfere in any way with the sanitary or domestic use of the water.

THE ADMINISTRATION OF FISHERY PROGRAMS

JOHN VAN OOSTEN, *Chairman*
U. S. Fish and Wildlife Service

EDWARD SCHNEBERGER
Wisconsin Conservation Department

E. B. SPEAKER
Iowa Conservation Commission

E. L. LECOMPTE
Maryland Game and Inland Fish Commission

JAMES R. SIMON
Wyoming Game and Fish Commission

HERBERT E. WARFEL
New Hampshire Fish and Game Commission

T. H. LANGLOIS
Ohio Division of Conservation

GEORGE W. BENNETT
Illinois Natural History Survey

H. J. DEASON
U. S. Fish and Wildlife Service

THE CHAIRMAN:

Last April I was requested to suggest a topic for discussion at this meeting. I suggested that we have brief reports from some of the Federal, Provincial and State agencies on the adoption of the objectives and principles of the American Fish Policy, formulated by this Society several years ago. A discussion of the policy was considered advisable in order to stimulate further action toward accepting its principles. I was surprised to be informed that not only was my suggestion approved but also that I was appointed as chairman for the discussion—whether as a penalty or as a reward for my suggestion, I do not know.

In discussing the policy, a consideration of the following questions by each participant will enable us to obtain the best index of how the American Fish Policy is operating at the present time:

1. Has any conscious effort been made by your department to follow or to use the American Fish Policy?
2. Of what value has the policy been in the administration of your fishery program?
3. Is the policy workable?
4. Have you any criticisms of or any suggestions for the improvement of the policy?
5. What can be done to make the fish policy more effective and more useful to your department?

In discussing these questions and the American Fish Policy in general the participants are free to discuss any phase of the subject.

DR. SCHNEBERGER:

Perhaps the most logical procedure in presenting our action in regard to the American Fish Policy is to follow a few of the points of the policy as they concern our activities.

Taking the first item, administration and regulation, the Wisconsin

Conservation Commission, composed of six men appointed by the governor with the approval of the Senate, has discretionary power. That is, the Commission establishes open and closed seasons, size limits, and other regulations, both on fish and on game. In using this power we are striving for uniformity of commercial fishery regulations on the Great Lakes. Some progress has been made in relation to the size limits and sizes of mesh. The Minnesota and Wisconsin regulations for the Mississippi River are, for the most part, identical. We are working with Iowa to bring about uniformity. We are also trying to develop a reciprocal agreement for the benefit of the fishermen.

As to propagation and distribution, we are following much the suggestions in the American Fish Policy with regard to stocking. Our plans of quota arrangements for bodies of water are very similar to those in New Hampshire. As the biologist learns more about the waters he is in a better position to make recommendations.

Our investigations on the boundary waters relate to the production of fish from the Great Lakes, and we are keeping detailed statistics of all phases of production. We have done nothing to improve the fishing gear; in fact, we have some undesirable mesh sizes that we do not want to preserve.

The grading and marketing of commercial fish should receive more attention. Marketing conditions for at least two species can be improved considerably. I refer to the smelt from Green Bay of Lake Michigan, and to the carp. Several million pounds of smelt are captured in the spring and the price declines to about one-half cent a pound. We have worked with the fishermen in an effort to develop methods of capture during the winter time when catches bring from 6 to 17 cents a pound.

Perhaps this is an opportune time to develop a market for the carp. During the present national emergency and era of increasing food prices, we are perhaps in a position to attempt, for instance, to develop tested recipes, methods of smoking and pickling, and so on, that can make carp really attractive and palatable and enable it to be utilized. Greater demand and utilization of carp will cause higher prices.

Our work in relation to fish diseases has been concentrated in the hatcheries. We have not attempted to control fish diseases in nature. We have adhered to the principle that prevention of disease is the best control; consequently we are trying to regulate our fish-cultural practices in such a way as to prevent overcrowding. The fish are fed good diets, and in addition we attempt to maintain what we term "hospital sanitation" in the fish hatcheries. We have had considerable trouble with furunculosis in a number of stations. By egg sterilization with aquaflavine and then culturing the eggs under clean conditions, at one particular station we have been able to control furunculosis and have not had an epidemic during the last 2 years. Ordinarily several sta-

tions had epidemic outbreaks. This summer we have had only three mild occurrences.

Pollution control in the State of Wisconsin is under the administration of a committee on water pollution consisting of members from the State board of health, the chief engineer, and representatives of the conservation commission. Our biggest problem is paper-mill pollution. Within the last year and a half the paper mills themselves have embarked on a program of the study of wastes. They assessed themselves ten cents a ton on their pulpwood, and that money goes into a fund for the purposes of this research. Approximately $70,000 has been obtained in this manner, and the work is in progress.

So far as personnel training is concerned, our department itself cannot do very much. We did have a State-wide system of public service apprenticeship 2 years ago under which every State department gave training to prospective state personnel. An apprentice served with my division for 2 years. I would like sometime to see a school of fisheries established in the Middlewest, as well as in other places, which would give training more specifically directed toward the solution of localized problems.

All license fees in Wisconsin are turned over to the conservation fund and used as such. In addition we have legislative appropriation for forest protection and development. Fines resulting from violation of conservation laws go to the school fund; we get no part of that. However, we do get the proceeds from the sale of confiscated articles. One-half of that goes into the conservation fund and the other one-half into a pension fund for the conservation wardens.

We have several agencies with which cooperation is being carried along. The Wisconsin Natural History Survey, about which most of you know, under Professor E. A. Birge, worked with our department for several years, and we sustained part of the expense involved. We carry on cooperative research with the State board of health in relation to toxicity limits, and we also cooperate with such federal agencies as the Fish and Wildlife Service and the Forest Service.

Education and publicity in Wisconsin are constituted practically as outlined in the fish policy. We have a monthly conservation bulletin, with a monthly edition of about 6,000 copies, which goes to all State libraries, schools, and even down to the small country schools. It goes also to judges and to various other organizations.

We have a few private fish hatcheries in the State, and we give them all the cooperation we can. With the increase in fishing we are encouraging the culture of bait minnows.

The objectives of fishery research have been in the main quite consistent with those of many of the other states, and I shall not go into that.

Referring to fishways in streams, the Barr fishway was developed in Wisconsin. It is going out of the picture now; it doesn't seem to be as effective as originally thought.

We conducted a few creel censuses and obtained valuable information from them. The censuses have not been as extensive as we would like them to be.

As to the improvement of fish-cultural methods, we followed the policy quite consistently.

With regard to the policy generally, it is very broad in scope; it covers practically every activity in fisheries. In fact it is so broad that I do not know that any State or Province can really follow it in its minutest details. I feel that approving this policy in 1938 was something like putting a shining light under a bushel; there was nothing said about it subsequently either at the meetings or in the *Transactions*, and I was glad to see it come out again. I believe it would be well worth while for the Society to stimulate interest in it, carry on additional publicity about it, and keep the administrators aware of the policy.

MR. SPEAKER:

I am disposed to say that Iowa has made a conscious effort to follow the American Fish Policy adopted by the Society in 1938. Obviously, it is difficult to follow any policy to the letter, since conditions vary in different States and in individual waters. The policy, however, did have tremendous value in serving as a guide for the administration of our fishery program.

I am going to mention rather hurriedly a few of the points of the policy. The first one, relationships between Federal and State agencies, Iowa's relations have been very favorable to the United States Government and the adjoining States.

Objectives of fishery administration and management; planning boards and priority rights of the fisheries. I think you are all familiar with our 25-year plan, not only in fisheries but in all other phases of conservation.

As to personnel training facilities, the department itself has not trained officially its personnel, but we have introduced into our State college courses which enable students to major in fishery work.

Private propagation—we have in our state only three private hatcheries, and they receive the support of our department.

We have followed the policy very closely in the management of fishing waters.

Referring now to the third part of the policy, objectives of fishery research, I would like to make a few comments. Iowa has been hatching and producing fish since 1872. Millions of fish have been poured into the lakes and streams, indiscriminately, in past decades. Some of these stockings have been successful and many of them have failed. We are of the opinion that the first requisite for successful stocking is to make a thorough inventory of all our individual waters. We have followed the policy of making a hurried survey on our major lakes

and streams during the past 4 years, and we expect to follow that up with a more comprehensive survey in order to produce better results and obtain a more sound fishery-management program. We have divided our state into five sections or regions and placed a competent fishery supervisor in charge of each.

We have attempted numerous improvements on the following lines of policy, including such items as fish surveys, stream and lake improvements, creel census and fishways. In regard to fishways, a very notable piece of research work was carried on by the Institute of Hydraulic Research at Iowa State University, with the cooperation of the Conservation Commission. In this connection we developed a very splendid fishway, which is described in the 1940 biennial report.

We have improved our fish-cultural methods and have established a definite stocking policy. We follow the application system previously used by the department, acting upon recommendations of district fishery supervisors, biologists, conservation officers and the central office personnel.

We have in Iowa quite a large number of natural or glacial lakes, varying from 40 acres to about 600 acres in area. These lakes are too shallow to support fish over the winter, consequently losses occur each year, and they were not satisfactory as fishing lakes. We cleaned these lakes thoroughly by seining and use them as refuges or nursery ponds. One lake of about 150 acres in area has been used for the last 10 years in the production of yellow pikeperch. Last year we planted 3,000,000 and produced more than 600,000 fingerling yellow pikeperch from 5 to 6 inches long. We believe that in our waters at least, the stocking of fish of this size is helping to restore our fish population. We have also established several nurseries which are very shallow, 3 or 4 feet, some of them ranging up to 40 or 50 acres in area. In other words, we are trying to utilize our limited waters to good advantage.

One part of our program which is not definitely mentioned in the policy is the removal of coarse or noxious fish. In Iowa we have concentrated our efforts on our major lakes and streams and are removing about 2,000,000 pounds of coarse fish annually. They are predators, and we are trying to balance the population of game species with the non-game species.

The pollution laws of Iowa are administered entirely by the State board of health. We assist the board in making surveys and give them whatever technical assistance we can. They have done a good piece of work. Hundreds of disposal plants have gone into operation in Iowa during the last few years.

We have been unable to secure legislation giving our conservation department discretionary powers. We did, however, have a law enacted in 1939, called the "biological balance law," which is very effective in that it gives our department the power to open seasons and close seasons in accordance with the biological balance. I am going to take this opportunity to read this to you, if I may:

"The open seasons, closed seasons, bag limits, catch limits, possession limits and territorial limitations set forth herein pertaining to fish, game and various species of wildlife are based upon a proper biological balance as hereinafter defined being maintained for each species or kind. The seasons, catch limits, bag limits, possession limits and territorial limitations set forth herein shall prevail and be in force and effect for each and every species of wildlife to which they pertain as long as the biological balance for each species or kind remain such as to assure the maintenance of an adequate supply of such species. The Commission is hereby designated the sole agency to determine the facts as to whether such biological balance does or does not exist. If the Commission, after investigation finds that the number and/or sex of each or any species or kind of wildlife is at variance to aforesaid condition, the Commission shall by administrative order extend, shorten, open or close seasons and/or change catch limits, bag limits and/or possession limits or areas in accordance with said findings. For the purpose of this section, biological balance is defined as that condition when all losses to population are compensated by natural reproductive activity or artificial replenishment, replacement or stocking."

Following that policy we are negotiating a cooperative research agreement among the Iowa State College, the American Wildlife Institute, the Fish and Wildlife Service of the U. S. Department of the Interior, and the Iowa Conservation Commission. The purpose of research to be conducted is to investigate waters in various regions of the State. The research efforts will be carried on as described in Article 3 of the American Fish Policy. The program will begin on major lakes and will be extended to other fields as time and funds permit. Individual waters will be carefully studied to afford a comprehensive basis for a better fisheries program. We expect to be able to improve our waters so that maximum yields will be attained.

We find that the policy is very workable in our state and seems to serve our needs quite nicely. The only suggestion I can make is that cooperating agencies should follow the policy a little more to the letter.

MR. LECOMPTE:

We know that the American Fish Policy as adopted in 1939 would be very beneficial if Maryland had the money to carry it into effect. The Department of Tidewater Fisheries and the Department of Game and Inland Fisheries are two separate and distinct departments. Our revenues are derived entirely from the issuance and sale of anglers' licenses—for fishery end of it; the game end of course from the hunters' licenses. Therefore we have very little to spend—about $30,000 from the anglers' licenses, which goes into a dedicated fund and can only be expended for the purpose of propagation and protection.

The Act which went into effect in 1939 divorcing the administration game and inland fisheries from the administration sea-food industry provided discretionary power, therefore we have the power to promulgate regulations in addition to the laws enacted by the General Assembly of our state. This power has enabled us to make some very

decided advances in following the fish policy, and I would like to refer to two or three of them.

We have on Cotoctin Mountain in the national park an area comprising about 30,000 acres in Frederick County in which one of our most beautiful trout streams is located. In 1940, in cooperation with the National Park Service, we set that area aside as what you might term an anglers' paradise. We eliminated the general act providing for state-wide seasons, limits and so forth, and fishing on that area was reserved entirely for the fly fishermen, and fishing was restricted from 8 a.m. to 7 p.m. The creel limit was 10 per day; we reduced it to 5. The plan has worked very satisfactorily.

In 1941, this past winter, we passed regulations and adopted practically that same policy on a few other streams in Baltimore County for the benefit of those who did not have free access to the Hunting Creek area. In April, 1941, we took over Gwynn Oak Lake, which is owned by the City of Baltimore and was operated by an amusement company. We established on it a "Kiddo" where children can fish. Under our law, any person over the age of 14 is required to procure an angler's license. The regulation with reference to this area provides that only those under 14 years of age may fish on that lake. They register as they enter and again as they go out.

We have made some stream improvements and wish we had the funds to make more.

I do not know what effect a biological survey would have in Maryland. With us it has been a fight every inch of the way before the committees of the legislature on game fish regulations. In the past few years the General Assembly has been far more liberal in dealing with conservation matters and has enacted beneficial conservation legislation applying to game fish.

We hope to continue to try to follow some of the methods recommended by the fish policy. I am sure the States that do will find it very beneficial.

MR. SIMON:

We have used the North American Fish Policy in two ways that have not been brought out so far. Personally I use the policy itself constantly, and have taken advantage of every opportunity to have the fish workers in the State refer to it in order to crystallize their own opinion about the general broad plan of fish management, and also in order that they may be capable of talking to the fishing public in the State.

Another way we use it is through our legislators. We have so few legislators in Wyoming that we are able to contact many of them throughout the 2 years intervening between sessions. I brought the attention of 30 or 40 legislators directly to certain parts of this North American Fish Policy and have seen that acquaintance with its pro-

visions reflected in their attitude toward the whole matter of fish management.

The policy also is used in introducing new management practices in the State. The management practices as such have not been described in the policy, but it is easy enough to back our work in regard to a certain management practice when we can refer to the North American Fish Policy, the very name of which is most impressive.

Still another way in which we get help from this policy as it is printed is in the fact that when we criticize the application system and are required to state why we are opposed to it we then refer to the policy and point out that in effect the policy says that the application system is no longer usable in planting fish. We therefore have other uses for the policy than our own immediate uses—our daily administrative work.

DR. WARFEL:

The North American Fish Policy has been the guiding light for the development of fish policy and management policy in the State of New Hampshire. Two or three things came to my mind as I listened to the speaker who preceded me, and you may be interested in hearing what they were.

In regard to cooperation between the State of New Hampshire and the Federal Government, we of course endeavor to enter into as close cooperation as possible. In conjunction with the State of Vermont we have worked out what seems to me to be a feasible scheme. Inasmuch as the Fish and Wildlife Service is interested in achieving the same objectives as we are, namely, providing the best possible fishing, we have taken it upon ourselves to cooperate in the operation of the coastal stations that exist in our part of the country. We have entered into a formal agreement, signed by the proper authorities, under which we provide a definite sum of money to operate each of the two stations of the Fish and Wildlife Service in our particular part of the country, the only stipulation being that we have control of the fish when they come out, a condition which, incidentally, due to the lack of transportation facilities, the Fish and Wildlife Service has been very glad to grant us in the past. The plan has several advantages. In the first place it enables us to get a very large proportion of fish of the size we consider legal, at very reasonable prices. Besides, I imagine that in giving these stations a little more money to work with they do a better and more efficient job.

Mr. LeCompte pointed out that his department depended entirely upon license sales for income, and said they were short of money. We find the same situation—of course we all do. We evolved a scheme a few years ago which strikes me as being a very good one. We asked the legislature to guarantee us an income of $230,000 annually. We

make up the difference in fees and fines, and where we lack achieving that $230,000 in a year the legislature will appropriate it to us, and it is appropriated to us from general funds, automatically. This plan has been in operation now for three years. Two years ago I believe the state put in about $18,000. Last year they put in $1,500, and this year, with the defense effort and so on keeping people's pockets full of money, I believe they are going to make something on us. It has not been decided whether we expend the excess or not, but we do not care.

I do not think we should lose sight of the advantages of having a limited income. For one thing it is demanded of us that we handle our money as efficiently as possible. Instead of making plans which depend upon achieving more income we try to make plans that depend upon getting more out of our present income. That, to my mind, is the much more efficient way, and it is the much more responsible way to carry out this job of managing the outdoor resources.

I wish to mention also certain advances we have made in the Northeast with regard to our commercial fisheries. Some of you are aware of the fact that some of the Atlantic Coast States have been agitating for a number of years for uniform legislation governing the products of the shore and inshore fisheries. That objective has been difficult to achieve, mostly because the interests of the States conflict to a considerable degree. Last year we succeeded to the extent that seven States in the Northeast signed a marine fisheries compact, with the consent of Congress. The commission to be established under the terms of the compact will study the marine fishery situation and bring back to the respective State legislatures the recommendations of this commission for action. Whether that is going to achieve the immediate results of uniform legislation or not, of course we cannot say, but it seems to be a step in the right direction, and our problems will at least be brought down to a common basis along which we will be able to build management programs.

During the past year the New Hampshire Fish and Game Department was granted discretionary power for the first time in a number of years. A few years ago we had a rather unfortunate situation develop when an advisory board was making oral decisions without due publicity, and the people got tired of not knowing what their rights or duties were in various bodies of water from one day to the next. The new act stipulates definite times every odd year for the promulgation of laws and definite dates for their going into effect. Regulations are promulgated only after hearings.

I do not know whether you know the history of the fisheries of the Northeast. It is the history of resources coming into direct conflict with just such developments as those that were referred to in a preceding panel discussion on multiple use of waters, particularly the power situation. New England for years had perhaps one of the heaviest concentrations of industrial development to be found anywhere, rich as it was in sources of natural power. The result was that

all the streams in the Northeast at some time or other had from 1 to 30 or more dams to provide power for various classes of mills. The effects of these dams were, first, to shut off migration of the anadromous forms; second, to spread the water out and thereby change the general ecological picture of the stream itself. These were questionable practices; they tended to reduce the fertility of the streams, which were never satisfactory as fishing areas. We have had some of these dams for 250 years. We do not like them; they have worked to our disadvantage; they have changed our whole set-up. We are just now beginning to make some progress in the direction of restoration and management of streams for use of some of our native fishes. We were for a long time and still are to a large extent dependent upon exotic forms that are brought into our State; forms more nearly adaptable to these changed conditions. Our countryside is now getting back somewhat to its original condition. Eighty-five per cent of New Hampshire is in wildland at the present time; only 15 per cent is under cultivation. We have an opportunity to restore the natural resources if conditions can be left as they are at the present time and be allowed to follow what is now the natural trend. When we see these huge power projects being developed, I would like to concur in Mr. Reid's statements in a previous discussion at this meeting that they are definitely being brought in and forced upon us under the subterfuge of National Defense. I happened to be in conference the other day with one of the members of our power resources board, which has control of the waters of the State. He said that one of the largest control projects in the State has double capacities, 3 inches for flood control and 3 inches as power reservoir. Hydrologists have estimated, for example, that on four major streams that enter the Atlantic Ocean on our coastline there is 35,000 available horsepower at the present time. Of the 35,000 horsepower available, 31,000 is now developed and 4,000 developed but allowed to lapse because the industries have moved. From the point of view of the community the development of the hydro-electric resources to this extent, taking lands out of taxable values by the imposition upon them of these huge structures, does nothing more than add a payroll to the community which of course is lost after a few years when the dam is constructed. The fishing effort in the existing reservoirs and streams is absolutely nil today. I could cite 50 examples in the State of New Hampshire where these structures as they exist are absolutely valueless from the point of view of the fisheries.

I do not believe the solution of providing better fishing in the Northeast is in creating more water. The solution of the problem, I think, is better management of the resources we have at the present time. I would like to see this organization support any resolution that the Izaak Walton League may propose and any movement that may be set on foot to oppose these developments.

DR. LANGLOIS:

The North American Fish Policy was prepared by a group of technicians who were instrumental in bringing about adequate appreciation on the part of administrative officials of the need for making use of technical considerations in an administrative program. We are all sold on what is included in this policy and it is not necessary for us to argue the matter or discuss its merits. We are asking principally that the administrators allow us to incorporate it into the action program of conservation affairs—the sort of things we have been discussing at this conference. I think we technicians need to recognize that an A-1 conservation job will be done when it is politically expedient to do so; and the reverse is true—when it is "political dynamite" to do an A-1 conservation job, it will not be done. Conservation administrations are principally a matter of adjustment among the various pressures that are brought to bear on administrators. That is the American system of government. We are not going to change it in a hurry. Some administrators have a sufficient appreciation of the need for adequate technical advice and assistance and we have no difficulty in getting their support in the sort of program we want to see adopted. Other administrators are not quite so minded. Over and over again I have heard the criticism—and I am sure most of you have—that things which are incorporated here and the sort of things we like to do are theoretical and impracticable, that an action program needs to be based on things that will show results.

A continuation of extensive fish distributions is part of that program. A few fish put out in a stream constitute something very specific. A small dam built across a farmer's creek is concrete and specific, and even though an extensive distribution of fish may not be called for, and even though an extensive program of small dam construction may not be called for, unless we as technicians can supply the administrators with something equally tangible and salable from his point of view he is not going to back us.

What we have to do is to consider carefully the sort of things that people are sold on who are bringing pressure to bear on our administrators. If the program we want to see in effect differs from the program that results from responsibility and pressure, then we have to supply substitutes, and it is up to us to supply support for the substitute program that will work. For instance, in Ohio, after raising a good many millions of fish we decided to tag many of them and find out what happened. We did that and results indicated that a wholesale distribution was not called for, that other types of activity were in order. Those other types of activity cost money, and you cannot spend the same dollar twice. In other words we had to convince the administrators first that we should discontinue some of the old practices in order to use those dollars for a better purpose.

January last, the Ohio Conservation Commission voted the abandonment of five fish farms. One month later there was a meeting of

the sportsmen, a state-wide organization, and the abandonment of those five fish farms was not even mentioned. The entire meeting was devoted to discussing the need for habitat improvement, consideration of headwater reservoirs and the improvement of streams to prevent soil erosion. The fact that the abandonment of these five fish farms was not even mentioned is an indication that the path had been fairly well prepared before that step was taken.

There has been a little conflict between our old-line fish-culturists and our young technicians. I think our young technicians can learn something from the old-line fish-culturists. After all they have been living on fish farms and raising fish for a good many years and they have seen a good many things that can be incorporated into the new program. It does not matter whether you raise fish in a lake or stream or a fish hatchery or rearing pond; you are trying to meet the needs of those fish. I think it is essential that these two groups recognize that they need to present a united front to the administrators so that a program of mutual benefit may result.

The Ohio Division of Conservation made good use of the help formerly employed in the hatcheries. We set up a stream improvement crew, with trucks and equipment, directed by a fishery biologist; and we attempted to put our old-line fish-culturists on these five abandoned fish farms. But it was not that easy. The division of conservation has been encouraging the propagation of bait, and we have actually been propagating a good many minnows and crayfish. Most of these fish farms abandoned as such were subsequently leased to a former employee who set up an independent business for the production of bait.

DR. BENNETT:

Probably I should not be here "sticking out my neck", but I wonder if this American Fish Policy is as progressive as it might be. There has been a good deal of what I consider pertinent research on certain phases of this fish-management program. Dr. Langlois of Ohio has mentioned the phase that has to do with artificial propagation of fish and the stocking of streams and lakes. I think that is now becoming more or less accepted, although I know a good many States have not as yet cut down on their artificial propagation. To my mind, artificial propagation is a good thing as long as it is restricted to the stocking of lakes that have no fish in them, in other words lakes that are in process of construction by the Soil Conservation Service or by other agencies in our States throughout the country.

In regard to fish surveys, a fish survey that was carried on 10 or more years ago is of very little value. The usual fish survey consists not only, let us say, of net catchs of the fish that are in a given body of water, but also of oxygen analysis, carbon dioxide and all the other things that go with that field work. If the fish are present in the lake

and no winter kill occurs, it is obvious that regardless of where the oxygen comes from fish will be found. All that survey material is very nice in print, but is it of any particular value, at least in instances where we know that the lake will support certain warm-water fish and will not support trout or some kind of fish that requires a certain habitat and characteristics?

In regard to the test-net catches that are made in any given year and provide a record of the fish in the lake at any given time, that is well and good. The lake will probably over a period of years contain these same fishes, but there is no evidence to prove that the numbers of the individual kinds of fishes are going to remain the same. The numbers of one kind may go up, while another kind may go down, so that an earlier biological survey of a lake may not indicate at all what the characteristics and the fish fauna are at the present time.

In a good many lakes, a certain type of fishing has been good for some time; then a period occurs where the black bass, if it is a black-bass lake, will fall off perhaps over a period of 5 years and may never come back. It is not sufficient merely to know about the fish that are in there for any given year and in what proportion. In order to remedy that condition it is necessary to manipulate that population if it is at all possible so that the catch will again be of the type of fish desired by the fishermen. Possibly at that time we may see what the difficulty is, but a biological survey say ten or twelve years previously gives no indication whatever of conditions as they are at the present time.

There is another point I would like to bring out in connection with conservation of fish and fish management. In Illinois we certainly are not utilizing anything like as much of the populations of our streams and lakes as we might. I estimate roughly that in most of our larger reservoirs 95 per cent or more of the fish produced year after year die a natural death and are never taken with a hook and line. In very few instances, one or two to be exact that I know of, have we any record of the lakes being over-fished in Illinois. One instance is that of a small pond which is on a recreation area belonging to a glass company. This pond is about 2 acres in area and is fished by the several thousand men who work in the glass plant. A caretaker keeps a record of all the fish taken out of the lake. In the first year the yield of fish from that lake was 377 black bass per acre, which is high. The next year the yield was not quite so high, and the third year it was even lower. This year we had the opportunity to poison that lake, and actually about 4,000 fish were obtained despite the previous years of intensive fishing. Most of the fish were small, but were growing at a tremendous rate, so that if the lake had been closed for a year the fishing would undoubtedly have come back to what it was previously. None of the species present was eliminated and all occurred in sufficient numbers to repopulate the lake if they had an opportunity. This 2-acre lake was fished by perhaps 2,000 individual fishermen. They

did not fish all the time, of course, but whenever they had leisure they went out and held a fish pole whether they got anything or not. A yield of 100 pounds of black bass per acre for our relatively rich soil would not normally deplete the fish population.

Perhaps then it would be desirable and practicable to eliminate some of the more stringent of our laws regarding the taking of fish. One law I would like to see eliminated entirely is that with respect to the illegal taking of all panfish, including crappies. I think if this were eliminated for lakes where there is an over-population of these panfish, including crappies, individual fishermen would be interested in taking these small fish because they would not be able to catch anything else. In lakes where there was not an excess population and where the fish had a chance to grow rapidly and reach a large size, the fishermen would not be interested in little fish and so would have a tendency to throw them back into the lake, so that the situation would take care of itself. All these points arise from the question that I had in mind—is our fish policy as progressive as it might be?

THE CHAIRMAN:

I have here a statement from Mr. James A. Rodd, Director of Fish Culture, Fisheries Branch, Ottawa, Canada, which he asked me to read. It is a very brief statement in connection with the North American Fish Policy:

> "The fundamentals or principles of the North American Fish Policy are practised and have been practised in the past by the Department of Fisheries for Canada in so far as they apply to Canadian conditions and jurisdiction, and personnel and funds permit.
>
> "The policy has not been of value in the administration of the fisheries by the Department of Fisheries for Canada inasmuch as it has not been quoted or referred to in support of legislation proposed or adopted.
>
> "The principles of the policy have been found to be workable in so far as they have been practiced by the Department of Fisheries for Canada.
>
> "No criticism to offer, but would suggest that inquiries be made with a view to a more comprehensive exchange of research data between the interested commissions and departments."

These are Mr. Rodd's replies to the questions I asked in the memorandum letter I sent out, and to which I have already referred.

DR. DEASON:

The Fish and Wildlife Service of the U. S. Department of the Interior is in an entirely different position than the individual States with regard to adopting and applying the principles of the North American Fish Policy. The Service is primarily an investigative and advisory agency, conducting fish-cultural work, fish-screen and fish-ladder construction and maintenance, and assuming regulatory au-

thority in specific instances. Its policies, program and functions are more or less specifically outlined by Federal law and by the "over-all language" contained in its annual appropriation bills passed by the Congress. For these reasons I can give you no complete picture of how the policy has been adopted by the Fish and Wildlife Service, but can indicate a few of the major instances in which the activities of the Service function and are being modified according to the broad ideals and objectives of the policy.

The Service's fishery regulatory powers are limited to the fisheries of Alaska and to the enforcement of the Federal law regulating the interstate transportation of black bass. The principle of "fish as crops" is followed in the regulation of the Alaska fisheries since the basic law awarding jurisdiction to the Secretary of the Interior provides that a 50-per-cent escapement of salmon must be provided for. Regulations, therefore, are revised annually and modified during the actual fishing season as circumstances in the fishery necessitate. Such a procedure requires close coordination of the fishery biologists and the fishery management agents in the field and the success of their endeavors, at least so far as the salmon work is concerned, is exemplary.

You are all familiar with the new policy of fish distribution announced by Dr. Gabrielson at the Toronto meeting last year. Henceforth the output of Federal hatcheries will be directed primarily toward stocking federally-owned and controlled lands in the national parks and national forests; second, to the stocking of other public waters in cooperation with State conservation agencies; and third, and provided any fish remain, to the filling of applications from private citizens bearing the necessary congressional endorsement and the approval of State conservation authorities. This policy will eliminate many of the conflicts, some of them imaginary, that have resulted during past years. Insofar as we will assume control of the hatching of the fish and their distribution on lands directly controlled by Federal agencies we may simultaneously adopt and recommend management practices that are consistent with the principle of fish as crops.

The regulation of the commercial fisheries, except those of Alaska and those under the jurisdiction of the International Fisheries Commission and the International Pacific Salmon Fisheries Commission, are under the jurisdiction of the individual States. Pursuant to its functions as an investigative and advisory agency, the Fish and Wildlife Service stresses the discretionary management principle for commercial fisheries rather than the outmoded system of enactment of State laws to regulate commercial fisheries. The management principle is embodied in the adoption of a system of license quotas by Maryland last winter in order to control the most important factor in commercial-fishery exploitation, intensity. The rate of withdrawal is controlled through limiting the number of licenses and a promised refusal to issue additional licenses until such a time, and in only such numbers, as the actual condition of the fisheries warrants. This

principle is certainly revolutionary in the United States. If, however, we consider the development in the light of regulation of other human activities it appears logical. Every "Tom, Dick, and Harry" is not permitted to operate a radio-broadcasting station, build a power plant, graze his cattle on the same plot of land with his neighbors, or do innumerable other things of his own free will. There is space and opportunity for only so many individuals to engage profitably and legally in these enterprises. Is not a similar principle applied to the fisheries simply good business judgment?

The Service advocates uniform regulations to govern fisheries of a single body of water shared in common by the States. It has championed the cause of uniformity on the Great Lakes for many years and it is lamentable that the progress has been so small and so subject to reversal. The recent Atlantic Coast Marine Fisheries Compact is endorsed by the Service whole-heartedly as a substantial medium for furthering the cause of uniform legislation, or better, management, of the commercial fisheries of the Atlantic Coast.

The Service conducts investigations not only in relation to the commercial fisheries but also with reference to the angling resources of interior waters. It has, consciously or unconsciously, followed the principles set forth in the fish policy. All of its scientific work is aimed at recommending conservation measures designed to insure that the resource will maintain the highest level of productivity.

The principle of fish as crops is again exemplified by our studies of commercial molluscs, principally oysters. By the operation of our experimental demonstration oyster farms, the oyster-culturist is able to secure up-to-date information on the best methods of improving his bottoms, collecting spat, transplanting growing stock to better feeding grounds, and controlling pests. The oyster industry, at least that of the Atlantic Coast, must rely for recovery on farming methods since various factors have reduced the yield and impoverished the potential productivity of so many public beds.

Pollution is one of the great enemies of the fisheries that we are striving to attack. Our strategy is purely from the investigational standpoint since existing Federal laws are administered by the Secretary of War and are interpreted to relate only to acts of pollution that menace or constitute a potential hazard to navigation. Enforcement of pollution control is a function of the States, and unfortunately State conservation officials have little or no voice in pollution control in many States and laws of a great number of States are notably deficient in meeting the pollution problem from the fishery standpoint. The report of the chairman of the Pollution Study Committee presented at this meeting has indicated our present pollution activities in connection with the defense program and I will not rehearse them further at this time. We strive to render all possible assistance to the States by investigating their pollution problems and recommending control measures, but if the States take no action—and many refuse to

take action because it is not "politically expedient" to do so—little progress can result.

Realizing the deficiencies in conservation education, the Service has embarked upon the venture of providing training for its own employees. An in-service training school has been established at the Patuxent Wildlife Refuge near Bowie, Maryland, where groups of selected younger field employees in the various investigative and operating divisions of the Service are given an intensive course of lectures and practical problems for a period of 6 to 8 weeks. Through the course the students become intimately acquainted with all of the functions of the Service, gain first-hand knowledge of administrative procedure, and learn more about their own jobs.

Closely associated with the general in-service training course at Patuxent is the fish-culturists' school at Leetown, West Virginia. Living and laboratory accommodations are available at Leetown for 12 students who are selected from various hatcheries of the Service and detailed to the school for a period of 8 weeks. The first 2 weeks are spent at Patuxent so that the students may hear general lectures and receive the course-work in general administration. The remainder of the course at Leetown is devoted to elementary instruction in fishery biology, physiology, nutrition and other subjects directly associated with fish culture. Part of the time is spent in the hatchery learning the newest methods of caring for eggs, feeding fish, combatting diseases and pests, transporting fish-cultural products, and stocking streams and lakes. The program is new and undoubtedly will improve as time goes on. It appears to be the best method of providing the practical fish-culturist with up-to-date information and methodology so that he may improve his performance on his own job.

These few highlights, I believe, will give evidence that the Fish and Wildlife Service is following those aspects of the North American Fish Policy that are directly related to its defined prerogatives in the fields of fishery investigation, management and fish culture.

AN APPRAISAL OF MANAGEMENT POLICIES FOR LAKES AND PONDS

R. W. ESCHMEYER, *Chairman*
Tennessee Valley Authority

HERBERT E. WARFEL
New Hampshire Fish and Game Commission

LLOYD L. SMITH, JR.
Minnesota Department of Conservation

STILLMAN WRIGHT
U. S. Fish and Wildlife Service

C. J. D. BROWN
Michigan Department of Conservation

LYLE M. THORPE
Connecticut Board of Fisheries and Game

A. RANDOLPH SHIELDS
Tennessee Department of Conservation

H. S. SWINGLE
Alabama Agricultural Experiment Station

THE CHAIRMAN:

The subject of this panel discussion is extremely broad. I think we are generally agreed that there are more and more demands for good fishing and also that the situation is complicated by the fact that we cannot use ordinary business methods in order to bring it about. Our problems would be fairly well solved and I do not think we fishery workers would be needed if the license fees for angling were raised to about $50; the supply then would meet the demand. The fish are the property of the people, and with every attempt to raise the license fee we are taking away from another group the right to use a resource in which they rightfully share ownership. However, we cannot have a great deal of money to work with and what we do receive must go a long way. We cannot raise the license fees to any great extent; not sufficiently to meet our needs for more money. What should we do with our limited funds and limited management facilities? We have the various tools and we are just beginning to realize that some of them are not as effective as we thought they were. We still do not know how to use many of our tools. We still cannot diagnose accurately many of our problems. Only recently have we learned some rather important things and many more need to be learned. The purpose of this discussion is to air different views on this pertinent question of diagnosis of management problems and methods of treatment.

The most important tool in the scheme of lake and pond management has been the biological survey. We are now concerned as to just what these surveys mean in terms of providing better fishing conditions. It costs considerable money to make an intensive survey and I think it may be a good thing to discuss the actual value of surveys as the basis for improvement of fishing.

DR. WARFEL:

I am happy to have an opportunity of presenting a progress report on the New Hampshire management program, particularly as it pertains to lakes. I have no doubt that you fishery workers have followed our survey procedures and published results, and I think a report of progress is due you.

When the survey was set up in New Hampshire the primary purpose was to establish a definite policy with respect to salmonoid fishes. The major sport fishery in the New England region is supported by the salmonoids and the major expenditures of funds have been made for the propagation and distribution of certain species of that group. These include rainbow trout, brown trout, landlocked salmon, lake trout, our native char, and finally the introduced Chinook salmon which is native to the West Coast.

Formerly we spent $100,000 to $150,000 annually for propagation and distribution. The results achieved, however, were so unsatisfactory during the middle of the last decade that the citizens of the State demanded and obtained a new administrative organization and a complete change in policy. It became apparent to the new administration that its first duty was to conduct surveys to secure basic information.

We surveyed at least 200,000 acres of lakes. In the Androscoggin and Coastal Plain Watershed we surveyed 23,759 acres; in the Merrimac Watershed, 93,000 acres; and in the Connecticut Watershed, 27,000 acres. From these areas of water we have recommended as suitable for salmonoid fishes: 4,000 acres in the Androscoggin and Coastal Watershed, 65,000 acres in the Merrimac Watershed, and 10,000 acres in the Connecticut Watershed. Attempts at management for one type of salmonoid or another had been made in the past for practically all waters that we surveyed. We were able to eliminate as potential salmonoid waters nearly 60 per cent of the area that we surveyed. We did not eliminate these waters entirely from our management program, however, because we were able to use them for one species or another of warm-water fish such as smallmouth black bass, predominantly. Other species such as white perch, bullheads, and pickerel also come into our management plan.

As a result of the survey data we have set up a definite program for our lakes and for the distribution and propagation of fish for stocking them. The first step in our improvement policy was to do what we call "reclamation work," which consists of a simple poisoning process for the purpose of removing undesirable species. By next October we will have reclaimed 10 lakes, of which 7 have been treated so far. We have stocked these lakes with various species of trout and chars with notable results. Three lakes that we "reclaimed" last year in September and stocked in late November provided remarkable fishing this past spring. On Back Lake in the northern part of New Hampshire fishing has continued good during the 4 year following poisoning and restocking.

The second step, which we are beginning during the coming winter, has to do with improvement of cover. In some of our warm-water areas we have outlined a program of "rebrushing" and shelf construction that we intend to follow in two areas. Obviously the results can not be determined for a number of years.

We also are giving some consideration to a program of fertilization. We have many waters that are not producing now for the reason that they lack basic fertility. We have analyzed soil samples from 22 of these areas and have found them very deficient in many of the constituents necessary for good plankton growth. Whether that deficiency necessarily carries over into fish growth we cannot say, but we are working on that assumption. We have not yet made definite attempts at fertilization; they will be made, however, as soon as we have analyzed the data so far accumulated and that which we expect to obtain.

The survey program has worked out rather well in terms of fishing from the fisherman's standpoint. We have been able to make definite plans for the hatchery production that we need to supply all waters in the State. Previously we placed in our hatcheries as many eggs as we had money to purchase or had brood stock on hand to supply; then we did what we could with the fish produced at the hatcheries. Now we are able to lay down a definite number of eggs specified by a production schedule that we can prepare 2 years in advance, calling for specific numbers of fish in definite areas. We also are able to organize our departmental budget on a much sounder basis than ever before. The possession of a certain amount of basic data (although not all we would like to have) has enabled us to plan ahead. If anything goes wrong we are able to modify the program without upsetting the work too greatly.

A definite program based on accurate data has many benefits. Last winter we were able for the first time to route our distribution trucks efficiently. We brought in the wardens and truck drivers, worked out our distribution plan, and plotted it on a road map. The previous year we spent $17,000 for the pay of truck drivers; last year that same expenditure was $6,500. Furthermore, by having a definite plan for our hatcheries we have been able to save up to $35,000 in hatchery operating costs, and at the same time turn out the same poundage of fish (although not the astronomical numbers we used to turn out).

We are convinced in New Hampshire of the value of a program of fishery management based on biological-survey data.

THE CHAIRMAN:

Do our surveys have a definite objective, and does an actual "follow-up" in management result? As the popularity of surveys increases I wonder if many are not carried out simply because somebody else is making them, and without any definite purpose. Obviously,

New Hampshire had a definite purpose and has developed a management policy from the surveys. In my opinion that is exactly what we should strive for. Some of the other States have conducted surveys and we would like to get opinions as to their value. Michigan has a somewhat different survey policy in that more time is probably spent on each individual water that is studied than in the survey programs conducted in other States.

DR. BROWN:

Michigan's lake survey probably is a little more intensive than some of the lake and stream surveys that have been carried on by the other States. We make an effort to secure physical, chemical, and biological data on each body of water that we have an opportunity to study. During the past 10 years surveys have been completed of about 500 lakes and 2 river systems in Michigan. Those acquainted with the methods outlined in publications of the Fish and Wildlife Service will know our approximate procedure. First we prepare a complete contour map of the lake which is done during the winter when accurate soundings may be made easily through the ice. Bottom-soil types and shore-line features also are recorded. Although each map costs considerable money because of the time and skilled personnel involved, we consider such a map essential for subsequent investigations, and many additional data are plotted (spawning areas, vegetation, etc.). We hope that sometime we shall be able from these studies to classify our lakes and streams in relation to certain likenesses and differences which are indicated. Our problem is a little different from that of some of the other States which have very few lakes and a comparatively small number of streams. Our work of mapping and surveying can continue almost indefinitely. I have stated that about 500 lakes have been surveyed in the last 10 years; from 5,000 to 6,000 remain to be surveyed. We hoped, originally, that by studying "sample waters" throughout the State we could be able to manage all of them; but those hopes have not materialized. We find that we are forced to plan for the management of each water as a separate unit. It is difficult to apply the information obtained from one lake in managing the fisheries of another that is "just over the hill"—they are so different. Perhaps when we have studied an adequate number of lakes some of these difficulties will disappear.

I have been interested in the work in Minnesota where attempts have been made to classify lakes on the basis of survey material. We have not been able to do that well in Michigan, as yet. We have a great deal of information obtained during our surveys that we can't find any good use for at the present time. However, the individual-lake management program that we are carrying on in Michigan is helping in a great many ways. As Dr. Warfel has said, it certainly does distinguish between waters that are fit for stocking fish and those that are

not. It distinguishes between trout waters and lakes and streams suit able only for warm-water fish, and does away with much of the promiscuous planting of fish in waters for which they are not suited. Consequently, we believe we are making progress with individual management; we still think it may be possible, ultimately, to classify the the lakes into "management groups" in relation to species of fish or on some physico-chemical basis.

MR. SHIELDS:

All of the Tennessee lakes are artificial bodies built by the Works Progress Administration; they range from 25 to 150 acres in area. We began to work with them when they were comparatively new, and since we have a very small hatchery capacity we had the good fortune of not being able to stock the new lakes heavily at the beginning of their existence. Our lake surveys were conducted principally to find out how those lakes were progressing.

The lakes may be divided into two groups; those operated and managed by the State parks and those operated and managed by the Division of Game and Fish. My particular duty is to formulate management policies on the basis of our survey work for both of these groups of lakes.

We have very good methods of keeping an accurate check of all of the fish taken from the lakes as well as those that go in. Our surveys have showed us that some lakes have been very much over-fished. In one 100-acre lake, for example, 900 fishermen were out on the first day to take 8 black bass each. With such fishing intensity we find that 3 days is about all the lake can stand and we then close it for a recovery period. This summer the lakes that were most heavily fished were opened for from 3 to 9 days at the beginning of the season and then closed for the remainder of the season.

Our lake surveys have shown us that sometimes we have an over-population of certain species and an under-population of others. As a result, we try to remove the species which are not getting along very well and concentrate on those species that do thrive in the lake. So far our results have not been analyzed completely, but we are beginning to use our information in the control and management of lakes that are very heavily fished.

DR. SMITH:

Minnesota has a great many lakes; I think our latest count totals more than 11,000. We also have numerous streams, but probably the lake fishing is much more of an asset at the present time than is the stream fishing.

Surveys have been conducted in all parts of the State. This year we are trying to concentrate our efforts so that definite management

plans can be formulated for certain individual areas. In this work we have had a great deal of assistance from the U. S. Forest Service, both in the Superior National Forest area and in the Chippewa National Forest area. Without that assistance we would have accomplished much less.

So far we have used the data from our surveys largely to determine what water should receive what species of fish. We have tried to separate the waters suitable for salmonoid fishes from those best adapted for warm-water fishes, such as bullheads and rough fish. In certain areas of Minnesota the fishermen consider bullheads extremely desirable. That is true especially in the extreme southern and western parts of the State, although many of the waters will probably support a good population of species that are considered more desirable game fishes. We believe, however, that it is not of much value to improve the stocks of game fishes as long as the local population prefers bullheads. The problem is simplified because bullheads are easy to rear and probably are more resistant to winter kill than any of the other species taken by the anglers.

The problem of winter kill is especially great in the southern and western part of Minnesota. Those, in the past, who have requisitioned fish for stocking have not recognized this problem and have stocked fish regardless of whether or not they would survive the very severe winters. In our lake survey we have tried to select the lakes where there will probably be periodical winter kill and hope to avoid stocking those waters.

We have not yet been able to apply the findings of our survey work to intensive management. We have too many bodies of water and too many demands to concentrate on any one area or any one group of waters. In some of the larger lakes which support tremendous fishing we shall have to attempt more intensive management procedure. A creel census taken on Lake Winnebigoshish over the July 4 holiday from six docks showed that about 4 tons of fish were taken by the anglers on those six docks in one week-end. That figure is only approximate since we were not able to make a complete census, but the fact that those six docks represented about 30 per cent of the fishing docks around the lake will provide an idea of the intensive fishing that some of the larger lakes are subjected to. In that particular situation, fortunately, the presence of a number of tributary streams promotes excellent natural reproduction.

We hope eventually to be able to make plans for all our areas so that the lakes can be *managed* and not merely designated for a particular species.

The stream surveys were begun a great many years ago by Thaddeus Surber and were continued by Eugene Surber. We now are undertaking a more intensive survey of some of these watersheds. Some of that early survey work has been invalidated, in a measure, by changes in natural conditions. This is particularly true along the

north shore of Lake Superior where there is a large number of trout streams. The country was heavily logged and subsequently burned over; many streams became almost worthless for trout. As the forest cover returns the streams are recovering and now the question arises as to how many trout and what sizes of trout we should stock in them. There also is a great demand for stream improvement in this area, and we think that our intensive stream survey will enable us to recommend the most effective measures for improvement. In many streams we shall not employ stream improvement in the ordinary sense of the term, but rather shall attempt watershed control, through water conservation and the control of erosion. I believe, as do all of you who have had any experience with stream improvement, that money can be wasted as readily in stream-improvement work as in any other activity. Without an intensive survey of the streams one is not in any position to determine whether or not stream-improvement work is justified. A properly planned stream-improvement program will bring great benefits. We will be working 10 years on such a program before we cover all waters, but I think we will get valuable results from our surveys.

DR. WRIGHT:

A large amount of money was available for survey work in the Rocky Mountain area during 1934 and 1935, and a number of survey parties were in the field. Reports have been made on a number of the surveys, but unfortunately the administrators in the western States have paid almost no attention to the recommendations of the survey leaders. For this reason I believe that survey work in general is not in good repute in the western States at the present time. A large amount of money has been spent and there have been no practical results from that expenditure. At the present time the tendency seems to be to investigate specific improvement problems in a particular stream or lake and to study that problem intensively in the hope of evaluating the changes in the fishery, and making recommendations for changes in management policy. It is on this basis that we are working at the present time.

MR. THORPE:

In a State as small as Connecticut the one objective of a survey is to make it possible to wring the last drop of fishing satisfaction out of each drop of water. We have possibly a viewpoint concerning the use of a survey different from that held by other States, but our problems also are different.

The survey that we have conducted during the last 3 years has covered the principal lakes of the State. We have made chemical and biological observations; in fact I believe that our chemical analyses of

lake waters are more detailed than those made in most States. It may be of interest to you to know that we have been able to establish a definite statistical relationship between inorganic fertilizers and plankton production, although I don't find any practical use for the information now that I have it. I think that in our attempts to improve fishing we should give our attention primarily to the fish. Consequently, a large part of our survey has been devoted to the study of the fish. We also have attempted to make all possible contacts with fishermen. We investigated the growth rate of game species in all our principal waters. We also have made an attempt to find out how successful anglers really are in their fishing. Under our present legislative arrangement we can secure authority to impose special legal size limits, creel limits, and open and closed seasons, and as soon as we have adequate information on any one lake we actually formulate our own regulations. In other words, if the legal length of pickerel should be 16 inches in a particular lake, we make it so; if we think the daily catch limit should be 6 rather than the 10 prescribed by the general State law, we make it 6. In many lakes which are over-populated, especially with yellow perch, we remove all restrictions on fishing. We simply are approaching our management problem from a business-like point of view. We know how successful anglers are and we try to give them the best fishing terms consistent with the productivity of each particular body of water.

Fishing "satisfaction" does not depend necessarily on the fertility of the water or on any other particular factor. I would like to tell you about our catch records for one lake. For the past 9 years we have had accurate records through a permit system. The lake in question was closed to fishing for a number of years prior to being re-opened. For the first 2 years after the lake was opened to public fishing the anglers obviously harvested a surplus of big fish, and they were quite pleased with themselves; in the later years, however, the fishing satisfaction diminished. During the 9-year period various plantings were made. Each year as the records came in it became more evident that the returns followed no pattern. One year the catch was largely yellow bullheads; another year it was pickerel or black bass, and constantly the fishermen all said the fishing was growing poorer. There did not seem to be any method of interpreting the data until we had reduced them to pounds of fish caught per acre per year. Then it became clear that there had not been any actual change in the returns from that lake. For 9 years the lake turned out essentially the same number of pounds of fish per acre per year. Fishing satisfaction had declined because of changes in the species composition of the catch. I think that fact gives us a clue as to how we can use survey data to improve fishing satisfaction. Some species are more favored by anglers than others. Fishing satisfaction depends upon a combination of kinds, sizes, and numbers. I think by an application of survey data we have a chance of making the catch composition fall into the sizes

and species that anglers most desire to catch. When we do that we probably have improved fishing conditions.

THE CHAIRMAN:

I think at this point we can sum up the discussion by saying that surveys that are being carried on are more than mere survey work. It looks as if the survey is really important in the diagnosis of our management problems.

In my opinion, undoubtedly the greatest accomplishment of the last 5 years or so has been the creation of more water areas. This increase of water areas has done more than any other one thing to meet the large demand for fishing. In agriculture, if there were a large demand for corn the farmer might meet the situation by cultivating his acres more intensively for that commodity; it is more probable, however, that he would plant corn on land devoted to other crops.

DR. SWINGLE:

For years in the South, and I believe in the North also, there have been many artificial ponds. As a general rule the owners have not known how to manage them. Throughout the South today, thousands of new ponds are being built, usually by farmers or by sportsmen's clubs. Farm ponds range from half an acre up to possibly 3 acres; sportsmen's and community-club ponds range from 5 to 100 acres.

We are working with the Agricultural Extension Service, which has one agent in each county throughout the State. If a farmer wants to build a pond he can go to this county agent and get the directions for its construction. He can get the technical assistance he needs to lay out the pond and some little aid (mainly of a supervisory nature) in its construction. We are also working with the Soil Conservation Service throughout the Southern States. That organization is sponsoring the construction of a large number of ponds on farms throughout the South and to some extent in the North as well. They also give service to the farmer. They will lay out his pond and tell him how to construct it but he has to pay for the construction. This type of pond is not expensive. Most farmers use their own labor to build dams with the result that the smaller ponds can be built for a cash outlay of $40 to $50.

The pond program has spread tremendously; probably so rapidly that more ponds are built than can be properly located. Furthermore, in a considerable number of States which are not favored with large fishing areas large numbers of these ponds will be built in coming years. That expansion is going to present new problems to those who are working for State conservation organizations. I should like to mention some of these problems.

It is most important to stock a new pond properly at the beginning.

Of the thousands of ponds which have been built in the South, extremely few were stocked properly. We must have the correct species of fish in the right quantity. In stocking a pond we also have to know how many pounds of fish can be produced per acre with proper fertilization. (Small ponds on farms are hardly worthwhile unless they are fertilized.)

To be profitable, a pond must yield a certain minimum production. Suppose a 1-acre pond produced 100 pounds of game fish per acre; a farmer can catch only 30 or 40 pounds of fish per acre per year out of it. Such a pond is relatively useless to its owner. If we are going to have small ponds we must increase their productivity. We have determined from a series of experiments the type of fertilizer mixture which plankton needs for heavy production. We began these experiments in distilled water in glass jars so that they would not be affected in any way by the type of soil in the bottom of the pond in which the fertilizer was to be used. The experiments were later carried out in ponds. We have experimented with limestone ponds and more or less acid ponds, from one end of the State of Alabama to the other. We make no survey of the soil because most of the productivity has to come from the water. Nutrient materials leach out of the soil very slowly, consequently we apply fertilizers directly to the water. After working for 7 years with various farm ponds we have come to the conclusion that unless the farmer is going to fertilize his pond, stock it properly, and care for it continuously, it would be better for him to be without one; at least in the southeastern States.

Another problem in pond management, especially of small ponds, is weed control. If weeds get into the pond—and we know of no way to keep them out of a clear-water pond in the South—the pond will be so full of weeds within 2 to 6 weeks that it will be ruined. In addition to blocking out large areas of a pond where no fish can live, and lowering production, weeds have other disadvantages. When a pond is full of weeds it tends to produce mosquitoes; therefore as a measure of public health our ponds which are set up in the back yards of farms must be kept free of weeds.

Our experiments have brought out this important fact: If a pond has been fertilized year after year the fertilization alone will control all under-water weeds in the deeper water of the pond and in the shallow waters as well. Any large surface weeds that become established in the pond are pulled out. This removal takes some time and labor on the part of the farmer; probably the weeds come in once in 2 years and he has to keep them out as they come in. In addition to keeping the bottom of the pond clean by fertilization, the farmer must keep the edge of the pond clean. He has to prevent plants that grow around the margin from falling into the water and forming breeding places for mosquitoes. By this procedure we have been able to convince public-health authorities in the South that the ponds will not constitute a malaria hazard. We are also able to convince our-

selves that there are no mosquitoes present because we go fishing in them.

Certain things must be done to prepare for a pond program. Someone must be available who has had experience and training in the management of ponds and the public must be interested in ponds. Records show that between the time that the scientist makes discoveries and the time that the public really applies them there is a lapse of about 20 years. We are trying so far as possible to eliminate some of that lapsed time. It is difficult. We have to work directly with the farmers and to see that they construct and manage the ponds properly.

We have probably had the best success by establishing experiments in ponds owned by certain men throughout the State. We go to a section in which there is no managed pond, and proceed to look for one which can be put under management. When we find a pond that is "run down" and is not providing fishing we take it over and by proper management we can usually provide the owner excellent fishing within a year. This pond, then, serves as a practical example in the community and as an incentive to others to operate ponds according to our recommendations. We can talk until we are exhausted; we can publish innumerable documents and pamphlets; but farmers won't know how to take care of their ponds unless they are trained under direct supervision to do so.

The impression may have been gained that we fertilize with superphosphate alone. We use a complete fertilizer such as is used on fields. In any section one of the first things the fish-culturist who is interested in pond management must do is to determine what fertilizer is best for the particular region, whether to use a complete fertilizer, or to depend upon the fertility from the soil. The principal aim in pond management is the maximum production of game fish and panfish; all procedure must hinge on that.

The main purpose of farm ponds is to provide fish for the family. We are trying to manage ponds so that they are of both economic and recreational value to the farmer. If they are valuable to him he will take care of them.

FISH-STOCKING POLICIES AND PROGRAMS

CHAIRMAN: T. H. LANGLOIS, *Ohio Division of Conservation*

THE CHAIRMAN:

It is our hope that a spontaneous discussion of the subject of fish-stocking policies and programs will give an opportunity to many of you to express your views, and that the discussion will lead to a greater coordination of effort. We are all interested in providing more fish and better fishing. There is some divergence in point of view regarding the necessary procedures to bring about better fishing. It seems to many of us that the various points of view should be brought out into the open and discussed freely so that we can see them clearly and all the better appraise the merits of each of the respective systems.

Many agencies are involved in the attempt to provide better fishing —Federal, State, and commercial. We hope to call upon representatives of each group and it is suggested that you make notes as the discussion proceeds and present freely your point of view.

In recent years there has been a feeling that too little time was available at the annual meetings of the Society for adequate discussion since the actual presentation of formal papers occupied most of the time of the meeting. It seemed to those of us who were concerned with preparing this program that this year the emphasis should be placed on the discussions. Therefore, we will have an opportunity to determine whether the discussions can be as profitable as some of us think they ought to be. There are many fish-culturists who can benefit by the experience of others.

MR. C. F. CULLER, *U. S. Fish and Wildlife Service:*

In a way it is putting me "on the spot" to ask me to speak on the Federal stocking policy, because that policy already has been established by the Director. We do, however, have a program on which we are working in cooperation with the States. I am located in Region 3, with headquarters at Minneapolis. Our work in that region is conducted in cooperation with State conservation departments to a very great extent. For instance, the Michigan Department of Conservation approves or disapproves of applications for the several species of both cold- and warm-water fishes. They may assist us in distribution when our own trucks are inadequate. In Indiana the same spirit of cooperation prevails. For a number of years the conservation officials have made our trout distribution in that State. We do not have a hatchery in Illinois at the present time. In Wisconsin the most cordial relations exist between the Fish and Wildlife Service and the State Conservation Department. In fact the same situation prevails in all the States: North Dakota, South Dakota, Nebraska, Minnesota and

Missouri. I wish to stress the fact that in all these States our applications for fish are placed before the State department for review and recommendation. In no instance will we digress from those recommendations.

We believe that it is within the province of the State to conduct the lake and stream surveys for the State representatives are in a better position than we are to know what species of fish are adapted to the waters of the State. We have an arrangement under which the State assumes the responsibility for planting fish in certain sections of the State and the Fish and Wildlife Service takes on the responsibility for other portions.

From my experience in these States where the fishing population is so large—especially in Michigan, Wisconsin, and Minnesota—even if there is a trend toward the opinion that fish hatcheries are not necessary and that natural reproduction will solve all the problems affecting fish of catchable size, I do not think we are going to kill all the fish-culturists or abandon all the stations, because, after all, what would become of all the new areas that are being created and need stocking? I have been more or less of a prophet—one without honor in his own country—and I will see how much of a prophecy this is: That within a reasonably short time the viewpoint of some of the prophets of the opposition will change materially. I want you to keep that in mind and see how close it comes toward fulfillment.

But with all this—the program we have outlined and the cooperation with the States—there are certain important questions and problems that sometimes make us wonder whether or not the work has proved to be worthwhile. There are basic problems whose solution does not come within the province of the fish-culturist, but which must be solved before the fishing is going to be what it should be. In the Middlewest, particularly in Ohio, Indiana, southern Michigan, southern Wisconsin, southern Minnesota, Iowa, Missouri, and parts of Illinois, a major problem is presented by soil erosion which has changed stream conditions to such an extent that natural reproduction in the streams is only about 10 per cent of what it was years ago.

Once when Dr. Langlois and I were on an inspection trip we were returning from a site that afterwards was selected for a fish hatchery. We were talking about the old days when the fishermen used to catch smallmouth black bass in Lake Erie, not by the hundreds or by the thousands, but by the tons and transfer them to the interior streams. What becomes of the smallmouth bass? Ohio tags them and finds that they are in the Ohio River between Indiana and Kentucky, or even farther away but the fishermen don't get them. Dr. Langlois stated that he thought that soil erosion had changed the biological aspect of the streams. The next day we visited a hatchery where the ponds were absolutely clear. Just over the tow-path was a stream at least 40 feet wide and from 1 to 3 feet deep. It was thick with mud; you couldn't see a bright patch 1 inch under the surface. I said: "Well, Tom, that

is the reason your fish leave home." It seems to me that we need a sound water and soil program, because we cannot have fish unless we have suitable water. Much credit should go to the Soil Conservation Service; they have an excellent program. It should, however, be coordinated better with fishery programs.

The Forest Service also is working toward erosion control. In northern Wisconsin, Michigan, and Minnesota the Forest Service is replanting large sections. Once the waters of that country are held at the source and not drained out of the country through drainage ditches, the stream level will be maintained and we will be able to make progress.

The average person thinks that because he has water he can have an unlimited number of fish, and that opinion seems to be held for both warm- and cold-water fishes. As a matter of fact a water is just as good as the amount of natural food it contains. In this fact, then, lies the value of stream and lake surveying; to find out just what the potentialproductive capacity of a water may be. Frequently, when we plant a can of fish we are going to have to plant a can of forage fish also. As to the planting problem, I should like to read this statement of policy as approved by Dr. Gabrielson:

> "It is the policy of the Fish and Wildlife Service to allocate or distribute the output of its fish hatcheries in the following order of precedence:
>
> "(a). Primary obligation will be in the stocking of waters on lands under the control of the Federal Government, these including national parks, national monuments, national forests, Indian reservations, Bureau of Reclamation reservoirs, areas under the control of the Tennessee Valley Authority, wildlife refuges administered by the Fish and Wildlife Service, areas directly controlled by the Farm Security Administration or other agencies concerned with the relief of agriculture, and any miscellaneous waters controlled or administered by other Federal Government agencies. For the purpose of this policy, ponds, reservoirs, etc., which are constructed on private lands with the aid and encouragement, either financial or otherwise, of the Federal Government, shall be included in the foregoing category.
>
> "(b). Secondary obligation shall lie in stocking State waters, including the lakes, streams, ponds, etc., which are open to public fishing. This stocking shall be carried on either by direct plant under the supervision of the Service's employees, by arrangement with State conservation departments, or by furnishing the fish in response to applications submitted by responsible organizations or individuals.
>
> "(c). After apportioning the hatchery output to meet the above obligations, any remaining fish may be utilized in filling applications for private waters, this term to be construed as meaning lakes, ponds, or streams which are not open to the general public and which are not commercialized in any way."

We have made some changes in our fish-cultural program under which two of our stations are now raising wall-eyed pike to fingerling size. Fry that were placed in the ponds at the end of May are now 3 inches long. Next year we expect to undertake the rearing of northern pike to the fingerling stage. In those hatcheries we are turning over the entire output of both species, northern pike and wall-eyed pike, to the States for distribution. If they were delivered on application some-

one might put northern pike into a black bass lake, and eventually there would be few of either. I have known that to happen .

MR. LEE S. ROACH, *Ohio Division of Conservation:*

Our policy of fish stocking in Ohio is that of stocking public waters, but it is based on the application system. The policy includes the investigation of the waters under consideration and the stocking of the species and sizes which are believed to be most adaptable and most needed in the particular stream or body of water.

As you all know, stocking is still the basis for most fish-management activities. Many investigations and researches on streams and lakes are conducted to determine the kinds and numbers of fish present and to discover the existence of deficiencies in order that fish can be added to bring the population to a satisfactory balance.

In southern Ohio, for many years, we stocked only species native to the waters and then only when need for stocking was apparent. Now the fishermen of that region are wondering to an increasing extent where all the extra fish are that they were supposed to catch after concentrated stocking had been conducted. For this reason we are attempting to establish in that area a sound method of regional management.

In Ohio we stocked thousands of breeding fish every spring and thousands more plus millions of small hatchery fish in the fall. These fish were placed both in streams and lakes. Much of my work during the past 5 years in the southern part of the State has been directed toward determining the value of our stocking program. The first fact we learned was that all of our stocked fish move downstream, for we have received reports on tagged fish from six States. From the southern part of Ohio they eventually reach the Ohio River which does not belong to Ohio. Peculiarly enough, however, our native fish apparently do not travel downstream but remain where they were tagged or within a short distance of the tagging locality. Fish stocked in the fall usually wait until spring before they move downstream. Fish stocked in the spring move downstream immediately. A few of them wait until the spawning season, but most of them begin their migration immediately. All species that we have stocked behaved in the same way—smallmouth black bass, spotted black bass, rock bass, catfish, crappies, and bluegills.

We have had returns of as high as 36 per cent of the fish stocked during a single planting in southern Ohio. In 13 counties in the southeastern part of the State, 37 per cent of the fish that were retaken were caught from the Ohio River. Ninety-nine per cent of the fish that were stocked in the streams of the counties along the Ohio River were recaptured in the river. Some of the plantings may have been made 50 miles from the Ohio River. In 60 days smallmouth black bass planted in an excellent stream near Buckeye Lake, which is near the

center of the State, had travelled 180 miles downstream and were caught at Eureka Dam in West Virginia.

According to creel-census data, less than one-half per cent of the southeastern Ohio fishermen catch stocked fish. We have 30,000 licensed fishermen in the 13 counties of southeastern Ohio. During the summer of 1940 they caught 1,601,000 fish, less than 0.03 per cent of which had been planted.

We operated nets for a year on a small test stream in southern Ohio to determine the kinds of fish and their relative abundance at various times of the year. In September, 1940, as a check, we poisoned the fish in the test pool and the test riffle of this stream. Spotted bass and rock bass were planted in a quantity equal (in weight) to the fish removed by poison. The next September we could find none of our stocked fish and as nearly as we could determine, suckers, minnows, darters, and sunfish were in the stream in nearly the same proportion as they were before the poisoning. In other words, that stream was capable of supporting a certain number of pounds of suckers per acre, a certain number of pounds of spotted bass and of rock bass, and a certain number of sunfish per acre. Fishing was not stopped during the recovery period. The fishermen were fully as numerous in this section after the poisoning and restocking as they were before. The recovery of the original numbers and kinds therefore was made in the face of fairly heavy fishing.

Our data on the results from stocking lakes were obtained more indirectly. We have tagged a number of fish. Of course our breeding fish are caught but we no longer obtain returns of stocked fish in lakes when 25 per cent of the breeders are caught. We have, also, information on the fishermen's catch per hour and population data obtained by means of trap nets. There are available further, records on all fish stocked since 1932.

Lake Alma was stocked with 156,803 fish between 1932 and 1936. Seventy-nine per cent were bluegills, 5 per cent were largemouth black bass, 10 per cent were bullheads, and 2 per cent were crappies. Trap-net data and fishermen's catch records indicate that the fish are caught in the following proportions: Bluegills, 11 per cent; largemouth black bass, 4 per cent; bullheads, 20 per cent; and crappies, 56 per cent. Heavy subsequent stocking of hatchery largemouth black bass has not changed the fishermen's catch or the percentage composition of catches.

We have several new lakes in which various species have been stocked in different proportions. New Lake Hope, a small lake of 120 acres, was stocked with several thousand fish, of which black bass made up 2 per cent. In the first summer of fishing 26 per cent of the fish taken were black bass. Bullheads were stocked in the proportion of 1 per cent but they were caught at the rate of 21 per cent. Channel catfish made up 40 per cent of the stocked population and comprised 45 per cent of those caught. Bluegills composed 29 per cent of the stocked fish but made up only 4 per cent of those removed by the angler.

Crappies made up 28 per cent of the stocked fish; none were caught.

When another new lake was stocked, channel catfish made up 3 per cent of all the fish stocked and 30 per cent of all the fish caught. Bullheads made up 48 per cent of all fish stocked and only 26 per cent of those caught. No green sunfish were stocked, yet green sunfish totalled 32 per cent of all fish removed from the lake by the fishermen. Bluegills were stocked to the extent of 48 per cent; 9 per cent of the fishermen's catch consisted of that species. Rock bass, suckers, and a few other species were caught by fishermen, although none of them had been stocked.

In Lake Jackson, another new lake in southern Ohio which was opened this year, the gates were partly closed last October and the lake stocked with extremely small numbers of bluegills, black bass, and crappies. The gate was closed and the lake completely filled about the first of June. On July 20 of this year the lake was opened to fishing and, according to our creel census, fishing in that lake, then only 50 days old, was six times as good as in any other body of water in southern Ohio. A total of 2,130 fish was removed on the first day, and of these 1,910 were native stock.

THE CHAIRMAN:

Obviously we have some basis for thinking that divergent points of view can come together. Mr. Culler has presented his opinion that soil erosion perhaps requires basic consideration in any fish-production program. Mr. Roach has indicated a number of situations in which natural production of fish without stocking apparently was quite successful. Of course, there is some question as to how effective stocking would be in waters which are otherwise not quite suitable. Some questions must now have arisen in your minds regarding the statements made by the two men who have spoken so far and I would like to hear some further discussion.

MR. C. N. FEAST, *Colorado Fish and Game Commission:*

In our investigational program in Colorado we have been concerned primarily with stocking policies for trout, because trout supply the principal fishing recreation in that State. We have found through our creel census that the only measurable result obtained from stocking effort has been through the planting of fish of legal size. Plantings of fish of less than the legal size have not yielded any tangible results.

We are confronted also with the problem of the fishermen who take the bulk of the fish from the waters before they reach spawning age and size. In the Gunnison River, where we plant each year about $20,000 worth of legal-sized rainbow trout, one-half of the catch is Loch Leven trout derived entirely from natural reproduction. In other words, we are obtaining 50 per cent of the catch from natural

reproduction in spite of the fact that 80 per cent of the fish are taken before they reach the spawning age. Now we are giving thought to proper seasons and bag limits for the fish that we desire to promote, and to the protection of the spawning individuals of that species, rather than to methods wherein we must give the fisherman $500 worth of fish for a $2 license fee.

DR. CLARENCE M. TARZWELL, *Tennessee Valley Authority:*

In the T.V.A. reservoirs it appears from the information at hand that during the first spring season of an impoundment when the competition is not so heavy we have a very large and successful production of young fish. There are indications that in the Wheeler Reservoir in the second year of impoundment we had a larger percentage of desirable game species, such as black bass, than we have had in any subsequent year. After the second year the numbers of black bass have had a tendency to decrease, whereas some other species such as crappies have increased. Of course, there have been few crappies planted until this year. Very few black bass have been planted; most of the stocked fish have been bluegills, red-eared sunfish, or hybrids between the two species. There seems to be a very successful natural reproduction. Population studies have been made during the present month. We found that an acre of water contained 11,154 young-of-the-year black bass (the total included a few red-eared sunfish) whose length averaged about 30 millimeters. That was on August 5. In a study made in May we found almost 800 yearling black bass per acre having a length of 1.25 to 2.0 inches. On August 5 we found 356 yearling black bass having an average length of about 4 inches. Probably that would correspond to our larger number taken earlier in the season.

We find that there is no lack of forage fish; indeed, I believe we would be glad to have fewer. We found 6,000 gizzard shad per acre having a total weight of 301 pounds in one of our areas. They were so abundant that they were crowding the young black bass, and averaged larger in size than the young black bass for which they were intended to provide forage.

In addition we found about 14,000 other fish in that area and there seemed to be no lack of young fish. The percentage was greater in our catch of black bass than in the population; they constitute between 3 and 4 per cent of the population. In the predominant species, bluegills, the ratio of young of the year to legal-sized fish was 272:1. We found 45 legal bluegills per acre in the area studied. If these figures applied to Wheeler Reservoir as a whole we would have to plant 18,000,000 bluegills over 1 inch long in order to increase the production by 1 fish per acre. In other words, we would increase the total legal fish per acre from 45 to 46 by planting about 18,000,000 fingerlings.

It seems that in fish management we should not consider one species alone; we should consider the total population of fish. There are so many so-called forage fish and so many rough fish such as carp and buffalo that planting the game fish in the insignificant numbers in which they have been stocked in the past might not have much effect in increasing the number of legal-sized fish, especially in view of the fact that natural reproduction will provide many more fish than we can plant.

MR. CULLER:

To me one of the great mysteries is what becomes of all the fish that are hatched. We have been carrying on an experiment for about 5 years in order to obtain some knowledge as to the number of eggs produced by certain warm-water fishes and some of the results are astounding. A 3-pound black bass had 101,900 eggs in the ovaries and a 2-pound 10-ounce individual of the same species had 247,000 eggs. A 6-inch sunfish carried 22,000 eggs. A 1-pound crappie that was 7 years old carried 168,000 eggs. One might presume that if even a moderate percentage of these eggs hatched our streams and lakes would be so full of fish that one could walk on them to cross the water. We are using this information in connection with our stocking of black bass ponds and in rearing operations at our stations. Where formerly we stocked 30 pairs to the acre of pound surface we now stock 4 or 5 pairs, and we have found that we are now obtaining a higher percentage of output at all the stations than we did before.

At one of our stations we produced over 40,000 2½-inch largemouth black bass per acre in a 4-acre pond. It seems to me that production, as I said earlier, depends primarily on food. There is no value in hatching fish in large numbers and then permitting them to starve to death or be destroyed by cannibalism so that at the end of the season a few large fish and no small ones remain.

DR. O. LLOYD MEEHEAN, *U. S. Fish and Wildlife Service:*

In Florida we are just beginning to understand stocking. In the first place, unless we have some knowledge of the fishing intensity on a body of water I do not see that we have any right to make an estimate of what we should stock in it. In certain lakes of the Ocala Forest we have been making population studies similar to those discussed by Dr. Tarzwell. In lakes which have clear sand bottoms with some accumulation of humus we found from 19 to 26 largemouth black bass per acre of water (including all sizes) and from 5 to less than 0.5 legal sized largemouth bass per acre. Those lakes have neither inlets nor outlets. The dry season in that particular section of the country occurs during the winter and spring, with the result that the lakes are probably at their lowest levels during the spawning period. Of

the five lakes on which we have made studies so far we have found fingerling largemouth bass in only one, which indicates that the survival is practically nil. The largest percentage of the population was between 5 and 11 inches in length and the average was between 7 and 8 inches.

DR. R. W. ESCHMEYER, *Tennessee Valley Authority:*

At the upper end of the Tennessee Valley where we made a careful check on the catch we found that, in 1939, saugers represented 3 per cent of the catch, and 9 per cent in 1940. We found that crappies constituted 1 per cent in 1939 and 6 per cent in 1940. They were not stocked. The smallmouth black bass has been increasing over the largemouth. The smallmouth was not stocked and the largemouth bass was. On the other hand, we have been netting since April in a section of the river which will be the Cherokee Reservoir and have found almost no game fish—only a few Kentucky bass and a few saugers. That water has been polluted; in another few months there will be 30,000 acres instead of the narrow river and the pollution may not do much damage then because of the increase in volume of the water. It looks as if we will have to stock not only fry, which have a very good chance of survival, but brood stock as well. As one of the critics of stocking, I now know of one place where I believe it will be very beneficial. Undoubtedly there are two sides to the question.

DR. A. H. WIEBE, *Tennessee Valley Authority:*

There is one point that neither Dr. Eschmeyer nor Dr. Tarzwell has mentioned in connection with the Tennessee Valley reservoirs. The amount of stocking in these waters, according to the statistics of the Fish and Wildlife Service and of the Authority itself, is not a drop in the bucket. These reservoirs have produced a great deal of excellent fishing in a short time. In our reservoirs in Alabama the fishing has been especially good and seems to be maintaining itself as is indicated by the fact that Wilson Reservoir, which is 16 years old, still provides good fishing. Alabama has never seen fit to establish a closed season, which is no criticism of fishery administration in that State. Good fishing has developed in the reservoirs and appears to be maintaining itself without either closed seasons or intensive artificial stocking.

I would like to ask you gentlemen some questions, and you do not have to answer them here; you can write to me next week or next year. I am responsible for the formulation of policies to take care of, within the next few years, more than 600,000 acres of waters for sport fishing and for commercial fishing. Shall I recommend hatcheries? Shall I recommend rearing pounds? Shall I recommend closed seasons? I would like to have the benefit of your advice.

THE CHAIRMAN:

A suggestion was made in a Cincinnati newspaper a while ago that might interest Dr. Wiebe. Dave Roberts, of Ohio, who is known to some of you, suggested that in view of current discussions and controversies over the effectiveness of stocking program and fish-management procedures we should use this new series of reservoirs as an experimental area—place heavy restrictions on one reservoir and none whatever on another; stock one very heavily and refrain from stocking another; and try to get some specific information about the values of the different procedures.

MR. HENRY C. MARKUS, *U. S. Fish and Wildlife Service:*

Other important factors are the species of fish with which we are dealing and climatic conditions. This spring a paper was presented at Amherst on the run of Atlantic salmon. A hatchery was built for the purpose of supplying landlocked salmon to a certain stream. The depression came along and the hatchery was closed. Five or six years after the hatchery was closed the run of salmon stopped. I understand that the hatchery has been in operation again within the last few years, and that a few salmon are coming back.

DR. JOHN VAN OOSTEN, *U. S. Fish and Wildlife Service:*

The particular subject under discussion is not really in my special field of research. The problem of the effectiveness of artificial propagation was put up to me time and time again and finally we were forced to try and obtain evidence as applied to the Great Lakes.

Most of you probably know that for many years the Great Lakes have been stocked heavily with whitefish and also to some extent with wall-eyed pike. Many of the fishermen have contended that this stocking was very effective. Their contention was based on the belief that several years after the plantings were made in their particular waters the number of fish increased. In other words they held that the planting of fish was effective in increasing or maintaining the catch in subsequent years. We thought that the best method of getting at the truth would be to secure a record of the number of fry planted over a series of years and try to correlate the plantings with the catch in subsequent years. In the paper listed on the program of this meeting I tried to correlate the catch of the whitefish of Lake Erie with the plantings of fry in the previous years. Using statistical methods we found an absolutely negative correlation. At the beginning of the period, 1920 to 1940—the period covered by the data—plantings were most heavy but the catch 3 years later was smaller than the catch that purportedly came from the smaller plantings. We also attempted to obtain some type of correlation between plantings and the later pro-

duction of wall-eyed pike in Saginaw Bay and likewise obtained negative results. Similar negative correlations between fry plantings and subsequent catches have been obtained in studies of the wall-eyed pike in two other areas.

On the basis of the results obtained we are forced to conclude that the plantings of fry have had no noticeable effect on the catch.

THE CHAIRMAN:

In talks with a commercial fisherman recently I learned a point of view that impressed me because of its frankness. Discussing the importance of the hatchery at Put-in-Bay in maintaining the supply of fish in Lake Erie he stated that fishermen were very much in favor of continuing the operation of that hatchery because they wanted to continue taking the fish during their spawning run, and that the operation of the hatchery and the procedure of taking spawn saved them from the criticism of sentimentalists who objected to the capture of fish during the spawning period.

MR. EUGENE W. SURBER, *U. S. Fish and Wildlife Service:*

I would like to call your attention to some of the stocking problems that I have encountered in a series of experiments conducted during the past 6 or 7 years. In the George Washington National Forest in Virginia we stocked large numbers of fingerling trout over a period of 3 or 4 years without obtaining any worthwhile results. I think the chief reason that better results were not obtained was that the water level of these streams becomes very low at times and that not many of the planted fish are able to survive to maturity. We have since abandoned the policy of stocking small fingerlings and are now obtaining satisfactory results by stocking legal-sized trout.

I think the importance of natural propagation should be considered very seriously. As a result of our experiments I believe that where natural reproduction is possible we should make full use of it. Let me give you an example. A year ago last August I destroyed all of the trout in a short experimental stream in Virginia by means of derris root. This stream, which rises from a large limestone spring, is only 1½ miles long. It has a flow of about 1,500 gallons a minute. All fish in that stream were destroyed from the head spring down to the mouth of the creek, but in the head spring we left 22 adult rainbow trout. Last fall we stocked about 800 trout averaging about 7 inches long. This year we removed about 20 per cent of the legal-sized trout that we had planted. The startling occurrence was the abundance of young rainbow trout in the stream this year that had been produced by the 22 adults that had been left in the head spring. Young rainbow trout produced by natural spawning are to be found throughout this stream. We have not stocked it this year and we do not plan to

do so, but I believe that the young fish resulting from natural reproduction will be fully adequate to produce the same total poundage of rainbow trout per acre that has been produced over the period of 7 years (we have removed 27 to 34 pounds of rainbow trout per acre from this stream every year).

Michigan, and perhaps other midwestern States also, have benefited by the planting of fingerling trout. I would like to hear from some of the Minnesota and Wisconsin men as to the policy they are following in stocking their streams. I know they have been making intensive studies on the stocking of legal-sized trout. They point out the benefit of natural reproduction, but no measures have been taken by the States, so far as I know, to establish upper and lower size limits which would enable some of the larger fish to help maintain the stock.

MR. FRED A. WESTERMAN, *Michigan Department of Conservation:*

In Michigan we are planting a great many fingerling trout. The tendency, however, is to plant more fish of legal and larger size. We were one of the States in the Middlewest that 12 or 13 years ago changed from planting fry to the planting of fingerlings largely because we did not believe that we were obtaining the results we should expect from the planting of fry. The trend toward planting legal-sized trout rather than fingerling trout followed because we did not seem to be getting satisfactory results from fingerlings. In brief, the wide disparity between the numbers of trout of either size that we planted and the number taken by anglers—as revealed by marking experiments on fish whose size makes it possible to mark them—was largely responsible for our engaging in more research on this entire trout-stocking question.

Three years ago our commission authorized the establishment of a stream laboratory on one of the northern Michigan streams in Montmorency County, near Lewiston, where we are endeavoring to obtain some answers to these perplexing problems. Dr. Justin W. Leonard, who is present, is in charge of that station. The work is by no means concluded; in fact, only certain phases of it have been undertaken. It is a long-term project and we are increasingly aware of the complex nature of the problem. Dr. Leonard may be able to tell you a few of the facts he has already discovered, such as the tremendous population of naturally-produced fry in some sections that were studied last winter. There seems to be a very great mortality between the time the fish hatch and the time when the anglers take them in their creels. That mortality relationship will vary widely according to the species of fish and the type of waters with which we are dealing.

It seems to me that there is great need for careful investigational work correlated with our hatchery program in order that we may be able to use the output of our hatcheries to the best advantage. I do not believe we are going to dispense with hatcheries, but I do think

that we will place greater emphasis on rational planting and less on total production.

For example, we found some small landlocked lakes that were filled with stunted yellow perch that were of no angling value. Our limnological studies indicated that some of these bodies of water were suitable for trout. By eliminating the undesirable yellow perch through poisoning and then restocking with trout we made some of these lakes very productive and incidentally lessened the angling pressure on other trout waters. We are finding from tagging and fin-clipping experiments that apparently the angler recovers a larger percentage of legal-sized trout from these pot-hole lakes than from streams. If this continues to be true the pot-hole lakes will receive more of our hatchery stock, because in most of these lakes there is no opportunity for natural reproduction. They support trout well but plantings must be made continuously.

On the Great Lakes, as has been mentioned, we continually are faced with this problem of artificial versus natural reproduction of some of our commercial fish. I had much to do with the discontinuance, 7 or 8 years ago, of the practice of issuing permits to Michigan commercial fishermen to take whitefish and lake trout during the closed season. I shall not discuss the reason; most of you are familiar with the problem. However, I do want to say that our research people should investigate this question further. Certainly I do not believe that we should increase the output of the commercial-fish hatcheries unless we can convince ourselves that the results justify it. The commercial fisheries of the Great Lakes are not in a prosperous condition—that is a long story in itself—but we need to know how we can best restore these fisheries.

MR. FEAST:

Colorado appropriated $200,000 for hatchery and rearing-pond improvement. I have been asked several times, in the face of publicity I am issuing regarding the value of natural reproduction and the failure in many respects of our artificial activities, why we have such an improvement program. I would like to explain that the improvements are being made entirely on economic grounds. Our studies have shown that the only measurable results came from plantings of legal-sized fish. Records of our hatchery operation showed that when we reared trout to less than legal size they cost from $2 to $5 per pound. By increasing our facilities and rearing the fish to legal size we produced less but reduced the cost per pound to 50 cents or less. We hope eventually to educate the people concerning the value of natural reproduction and proper seasons to protect the spawning fish. Then we shall use our rearing ponds—not hatcheries—only in a supplementary role.

Where we have made field studies we obtained as high as a 50 per

cent return for the first summer on our plantings of legal-sized fish, and we recovered as many as 10 per cent after the first season.

MR. CHARLES O. HAYFORD, *New Jersey Board of Fish and Game Commissioners:*

New Jersey is a small State and its streams are limited. We have a little over 3,000 miles of stream of which only 1,475 miles can be used, while 195 miles of the 1,475 can be considered worthwhile fishing streams. Our streams are very small compared to the ones most of you deal with. We have only 235 ponds and lakes. The largest lake is 9 miles long; the remainder are from a half-mile up to 2 or 3 miles in length.

With a few exceptions we have had no natural reproduction from trout stocked in New Jersey. Out of our 1,475 miles of stream there probably are not 25 miles in which trout will spawn. One of our best fishing clubs has 12 miles of the best trout stream in the State; if fish should reproduce anywhere it would be in those waters. The stream is not over 20-30 feet wide on the average. For years large numbers of trout have been planted but the quantity of fry and fingerlings introduced had absolutely no influence on the catch. Only legal-sized fish yielded returns.

In 1921 or 1922 we planted nearly 4,000,000 fingerling trout and I think it is safe to say that the anglers did not catch 4,000 of the 4,000,000. Then we enlarged the hatchery and planted nothing but legal-sized fish. Now we plant 650,000 legal-sized trout each year. They will have a total weight of approximately 125 to 150 tons. Our program requires large amounts of food; it costs us $40,000 to $50,000 a year for food alone at an average cost per pound of 4½ cents.

For some species stocking has not been necessary. In New Jersey we have not propagated pickerel. The pickerel catch, without any artificial stocking, is either holding its own or increasing.

In 1916 we planted 6,000 black bass fingerlings but now we plant from 200,000 to 250,000 a year. The black bass catch seems to be increasing in the various lakes. Originally, we planted the black bass when they were 1 to 1½ inches long. Since the results were negative we now are carrying them until they are 2½ to 4 inches long. We feed the black bass just as we do the trout. We find that we produce twice as many in a pond by hand feeding. Feeding is cheaper than building more ponds and hiring more men.

We have done a good deal of work with bluegills. Crappies are increasing in all the waters where we have stocked them from water-system reservoirs. Crappies cannot be reared satisfactorily in a hatchery.

The number of fish to be planted offers an important question. Why should we plant 50,000 fish in a given area? A farmer would not plant 50 bushels of wheat to an acre, nor would he try to keep 25

cows in a half-acre pasture. We need more scientific work as an aid to the fish-culturist.

I think, too, that we have planted many fish that were not in good condition. In 1917 we decided to give up the propagation of brook trout. I think we had 250,000 of them and at least four-fifths of them died from furunculosis when they were 6 to 7 inches long. We learned to control diseases, however, and today the brook trout is the most successful fish in our hatcheries.

THE CHAIRMAN:

Some of our ponds in Ohio were producing the same poundage of fish year after year regardless of the species being reared or the number of breeders. For instance, one year we put in 6 bluegill breeders and the next year 120. The poundage of young resulting came within 5 pounds of being the same in the two years. There was a large difference, of course, in the sizes of the fish. Smith and Swingle of Alabama will tell us we could have done better if we had fertilized the ponds a little more. I wonder if we could have some discussion as to whether every water area has its own productive capacity so that any improvement of fishing really involves increasing the fertility of the bottom and the quantity of natural salts in the water.

MR. W. F. CARBINE, *Michigan Department of Conservation:*

During the past 4 years we have been making a study on a little 15-acre lake north of Ann Arbor. We have been watching the fish spawn and recording the number of nests and attempting to estimate the number of fry produced per nest of each species. Of course we do not know as yet how many of these fry have survived and will not know until this fall, when we plan to destroy the fish with poison and thus determine the total population.

We have found that bluegills, sunfish, and rock bass will nest on almost every type of bottom that is available. Largemouth black bass are equally versatile. For bluegills we found an average of 17,000 fry per nest over a period of 4 years. Our counts have not been completed yet for sunfish but the average is somewhat lower; about 7,000 or 8,000 fry per nest. Data are inadequate for largemouth black bass but the average will approximate 7,000 to 8,000 fry per nest. This lake has not been stocked for from 15 to 20 years. Yet it is producing more fish than are taken out by fishing each year. The bluegills and sunfish grow slowly; it requires approximately 5 years for them to reach legal size. Of course, the lake is not fished heavily.

DR. H. S. SWINGLE, *Alabama Agricultural Experiment Station:*

In Alabama we have very little fishing area except that which we provide ourselves. Consequently we are very much interested in

ponds. We have an old 30-acre pond for which we have fishing records over a period of 16 years. We have tried various methods of improving the fishing in that pond. First we built a half-acre brood pond at the upper end of it. We stocked every year with 5,000 to 40,000 bluegills. When we began this experiment we were catching 2,800 bluegills per year; when we finished we were catching 800 to 900. We then tried planting largemouth black bass. Having heard that it was desirable to stock large fingerlings instead of fry, we planted about 2,000 to 3,000 largemouth bass 8 or 9 inches long. At first we caught few fish. The next year we took some fish 8 or 9 inches long but not quite so many of them. Then we waited another year and took fish 8, 9, or 9½ inches long, but fewer of them. Eventually these fish disappeared from the pond; I presume they were eaten by the old fish already there, but they never did increase the catch of fish in the least.

Then, to make it worse, we decided to try the white crappie, a species that did not occur in the pond at that time. The first year they grew rapidly from fry to a length of 6 or 7 inches. But when they reached that stage they did not grow any more, with the result that it is impossible to catch legal-sized crappies in that pond. Little crappies can still be caught. All these facts simply emphasize the point that a pond is capable of producing a certain amount of fish. It was an old pond which already contained the amount of fish it could support. We did nothing but harm when we added more fish.

In other investigations we have drained a large number of ponds whose age varied from 2 or 3 years up to 20 or 30 years. As Dr. Wiebe has said, we have no closed seasons and few places to fish in Alabama, so that heavy fishing occurs on all suitable waters. Nevertheless, we have never drained a pond that did not contain enough small fish to utilize every bit of food available if we had taken out every legal-sized fish. I might mention what happened in connection with a lake just below the State fish hatchery. For years different persons had been writing to the fish hatcheries for fish; they wrote also to the Federal Government, and to neighboring States; and everybody gave them fish. The pond was stocked for years and years and had as poor fishing as one could possibly imagine. Finally they became disgusted and bandoned stocking for several years. Then we made an experiment in that lake. It was drained and from the 25-acre area we recovered about 250,000 young bluegills, 1 to 1½ inches long—more bluegills than were being produced in the State fish hatchery. The fish hatchery distributed them for stocking more than 1,000 acres of water. We found that in addition to the legal-sized largemouth bass that pond contained about 3,000 small fish of that species, which is enough to stock about 100 acres of water.

We have finally reached the conclusion that so far as pounds in the South are concerned stocking is totally worthless. The only way by which we have ever increased fish production and the catch of fish in any pond in Alabama has been by increasing the supply of food avail-

able to the fish. By the use of fertilizers which increase the food we can provide excellent fishing in ponds that formerly were unproductive of fish attractive to the angler.

THE CHAIRMAN:

We have been talking about the early heavy mortality of young fish produced naturally as well as of those propagated artificially. This mortality suggests that over-production of fry brings about high mortality and that maintenance of a smaller brood stock would lead to the production and survival of more young. If that is so, many of our legal restrictions as to length, bag limit, sanctuaries, etc., are not sound. We are beginning to wonder just what would be the effect on our fisheries of removing all restrictions and spending the money involved in policing for the construction, for example, of headwater reservoirs.

MR. E. B. SPEAKER, *Iowa Conservation Commission:*

I think the answer to the question Dr. Langlois has just asked will depend upon the angling pressure upon the various bodies of water. We have had some experience in Iowa recently which I think will bring this point out more clearly. We have been building artificial lakes and restoring natural waters by dredging. About 4 years ago we dredged a lake of about 900 acres which we opened for fishing for the first time this year. We kept a careful creel census on the lake. On the opening day there were 6,000 fishermen, and in the first 7 days they took 80,000 fish in this one lake. I believe in a situation of that kind it would be impossible to expect natural reproduction to keep up with such a terrific drain on the fish population. I do think that under more normal circumstances natural reproduction within lakes will probably be adequate, but as I said before, in certain cases the stocking of fish of legal size or of near legal size is necessary in order to maintain fishing.

We have been rearing fish in Iowa since 1876. We found that as angling increased the quality of fishing sharply decreased. For many decades we stocked fry and small fish with apparently no success. About 12 years ago we turned to the stocking of larger fish in the overfished areas and found a marked improvement in fishing conditions. In trout streams, which are very limited, we stock legal-sized fish exclusively, and estimate from creel-census records that about 75 per cent of the fish stocked are retaken. Consequently we stock each year about 4 to 6 million fish, from 4 inches long to legal size. The totals include all species and about 250,000 are legal-sized trout.

MR. JAMES A. RODD, *Canadian Department of Marine and Fisheries:*

Doesn't it seem that we need first to ascertain, if possible, the deficiencies in nature? Having learned them we can then go a step fur-

ther and ascertain what are the causes of the losses that occur among natural fry as well as among stocked fish. We have learned without any doubt that eels are responsible for losses in trout and salmon streams that run to the sea. We have also found in several instances, both on the eastern and on the western coasts, that the losses in salmon were due entirely to oxygen deficiency. In one eastern river, salmon that came in from the sea in excellent condition were dead within 24 hours. These included not only adult salmon but young sizes such as parr and smolt.

Reference has been made to the effectiveness of stocking. In Canada we have two small areas in which sebago salmon occur. The local people place a great deal of value on these small populations. The eggs are collected in small creeks running into the lakes, and as the collection is quite small, the distribution from the hatchery also is small. The fish that are planted are marked by the removal of two fins. The percentage of fish we have recaptured during the last 3 years has ranged from nearly 30 to as high as 40. Furthermore, a very high percentage of all the fish caught by the anglers are marked hatchery fish. Obviously, under certain circumstances where natural reproduction is not satisfactory the return from a given body of water is wholly dependent on plantings.

THE CHAIRMAN:

We seem to be agreed that every body of water—stream, lake, or reservoir—is "a law unto itself". We need to make an investigation of each particular body of water and adjust our practices accordingly. In some of them, apparently, stocking is definitely desirable; in others it might be detrimental rather than beneficial. To condemn a system because it is not universally applicable is not exactly reasonable.

MR. ROACH:

We have one body of water in southern Ohio in which it seems that this year the stocking of young fish is going to be necessary, but the conditions are unusual. This lake was built recently by the U. S. Resettlement Administration. It was intended primarily for recreational purposes other than fishing, including boating, swimming, and as a location for cabins. In the drainage area of this lake are 15 coal mines. The lake has been acid since its construction. Fish can live in it and there is a small permanent population that supports reasonably good fishing. Nevertheless the acid nature of the water apparently has hampered reproduction, possibly by affecting the fertility of the eggs.

We have studied two small bodies of water within 20 miles of each other. When we drained them to determine the fish populations, we found that one of them carried fish at the rate of 25 pounds per acre

while the other contained over 450 pounds per acre. They were simply located in soils of different richness.

Buckeye Lake had no red-eared sunfish until 1934, when 56 were introduced. There is no bag limit nor length limit on red-eared sunfish taken in that lake. In 1939, by intensive trap netting we actually handled 5,000 red-eared sunfish and the data indicated that the total population was many times that number. Here a few breeding fish furnished a large stock even though there was no legal restriction on fishing.

The little lake I said was carrying 450 pounds of fish per acre now contains a tremendous number of bluegills, all about 5½ inches long. In 13 months we have found absolutely no change from this average length. I don't know whether they should be considered stunted, for apparently they are healthy fish and in good condition. The area of the lake is only 2.6 acres. Fishing is fairly heavy. No cover or spawning devices have been installed, although there is a considerable amount of aquatic vegetation present. The average depth is 6 feet and a considerable part of the bottom is suitable for spawning. Apparently the bluegills spawn in large numbers; the young move into the fringe of vegetation around the edge where they are protected from larger fish. As a result, a population of about the same average length and the same numbers has been maintained for the 13 months we have had the lake under observation.

MR. CULLER:

After some years of experience with the construction and operation of fish-cultural stations throughout the country it is my belief that each fish hatchery, each lake, each stream, offers individual problems. That is especially true at hatcheries, particularly as concerns food and water supply. I have had a dream that some day we will be provided with regional biologists. Through them we will find out just what has to be done, what chemicals can be added to water to obtain the maximum production per cubic foot of *Daphnia* and other forms. We will have also a biochemist with a travelling laboratory who can analyze the water at the hatcheries and inform the fish-culturist concerning what chemicals can be added to increase the production. Maybe I am talking improperly because, after all, fish may not be needed for stocking; natural reproduction may take care of our needs. Then again, we may need the additional fish that I believe can be produced by this kind of organization. It is my belief that we can double the output of the hatcheries by having such an arrangement put into effect.

MR. WESTERMAN:

So far the discussion has dealt largely with policies rather than actual practice. I have made a few notes, including a brief review of some of the trends in trout culture, that I think may help to open this topic for discussion.

This subject, in which all fish-culturists have been very deeply interested, dates back to the time that artificial propagation was first considered in this country. The Federal Government, the various States, the Dominion, and the Provinces, and even to a considerable degree the commercial fish-culturists, have leaned very largely toward trout propagation in its various phases. I think I am safe in saying that more money is expended in this country in the artificial propagation of the various kinds of trout than on warm-water fishes. Especially is that true in the northern part of the United States, in the western States, and in the Dominion of Canada.

I place brook trout as first among the individual species, with brown trout second, although there may be a question as to whether brown trout or rainbow trout deserves second position; fourth comes the lake trout. The first three are rather generally recognized throughout the country as sport fish, whereas the lake trout is both a sport fish of considerable importance and a commercial fish of the Great Lakes region.

The general trend in trout culture over most of the country, as was mentioned earlier by another speaker, has been toward the rearing of fish to larger size. This program had its beginning in the eastern States and moved westward across the country. Michigan, like other States, adopted it within rather recent years. Now, the adoption of this principle involved quite a considerable change in hatchery practices. Certainly a program which consisted of planting trout as fry was quite different from one that involved carrying the fish through to the fingerling stage or even to legal size. In Michigan it meant considerable modification of hatchery procedures. Due to conditions that prevail there, the development of fry that were to be planted had to be somewhat retarded in order that the fish might be held until the streams were at least approachable in spring after the snows melted. Many times those fish were planted under very undesirable and unfavorable circumstances.

As the rearing of fish to greater sizes progressed it seemed desirable to encourage the largest possible growth in the shortest period of time, and growth, as we all know, is influenced considerably by two important factors: First, the temperature of the water in which the eggs and young fish are carried; and second, the amount and kind of food the young are fed. In order to meet that situation in Michigan the eggs and the fry had to be handled in spring water, in order to take advantage of the higher ground-water temperatures. Then in midspring, sometime in May, these fish were transferred to streams that had higher temperatures than were found in the spring water supplies. In Michigan spring-water temperatures run fairly close to 45 degrees at their source. We have at least one station where the water supply is so close to the hatchery building that there actually is no noticeable change in temperature at any time. The water in streams, however, is affected by the weather conditions. We usually find streams whose summer temperatures rise to the maximum limits that trout will tolerate.

In our rearing ponds we find it quite desirable to have temperatures between 55 and 65 degrees. Sometimes the maximum may exceed 65 degrees. However, we do not find 70 degrees objectionable under certain conditions if it is not continued too long, and we have found that trout will stand even higher temperatures for short periods. Crowding of course becomes more dangerous as the temperatures increase, but the rate of growth, until one approaches the higher limits, certainly rises as the temperature increases. Consequently, by a combination of the use of spring-water supplies in the winter and warmer supplies in the summer it has been possible to increase tremendously the rate of growth of trout in hatcheries and rearing stations over that which takes place under natural conditions. We have had rainbow trout and brook trout whose length exceeded 10 inches at the age of one year. I am sure that in some of our streams trout do not reach 10 inches in less than 4 or 5 years. I am trying to bring out growth under artificial propagation as compared with growth under extreme natural conditions.

In securing eggs for our hatcheries it has been considered desirable to obtain eggs relatively close to the hatchery in which they are to be developed. In Michigan we depend very largely on commercial hatcheries for our supply of brook-trout eggs. We find it desirable to produce our rainbow-trout eggs by carrying brood stock.

Another important factor that all fish-culturists, particularly trout-culturists, must consider is the question of food for the growing trout. This problem has been intensified by the fact that many States are rearing trout to larger sizes, and also by the fact that other industries are interested in the products that were generally available to fish-culturists for feeding trout. Some packing-house products that used to be plentiful and cheap are now becoming scarce and expensive. We are all faced with the problem of trying to find satisfactory substitutes. Although considerable progress has been made, there is still room for improvement in that field.

Some States are using quite satisfactorily a combination of fish meals, cottonseed meal, skim milk, etc. Others are using low-grade fish of one sort or another. The State of Wisconsin is still continuing the use of canned carp with good results. In that way they are trying to utilize the surplus carp from some of their lakes. I understand that they can the smaller unmarketable carp that otherwise would be wasted. There are some canned fish foods sold commercially that we are using quite extensively in Michigan and we are also experimenting with both fresh carp and frozen carp. I believe fresh carp is the more satisfactory. A problem in the use of fresh carp is lack of available space at the time when they are most seriously needed. Accordingly, we are trying frozen carp during the part of the season when our greatest demand for food arises, which is during the later summer months. We believe that frozen fish has real possibilities as trout food, not as a sole diet, but supplemented with other foods. I think we agree that sheep

liver, beef liver, beef hearts, and other commodities still are an essential part of the food of hatchery trout, at least of the younger stages. It is going to be difficult to find a satisfactory combination of substitutes.

This problem of food has also led us to consider the development of a central station for the processing of trout food. We have particularly in mind the preparation of the food at such a station for use at hatcheries or rearing stations to which it would be delivered by refrigerated truck. By some such method as this the refrigeration problem at some of our rearing stations would be reduced if not largely eliminated. I believe also that if we could use labor-saving machinery in the grinding and mixing of the food we could make use of scientifically compounded rations. At present each of 15 or 20 fish-culturists prepares his own rations according to his own formula. A central food station might not be practical in some States. Preliminary consideration has indicated, however, that in Michigan we could serve about two-thirds of our trout hatcheries and rearing stations without having to make trips that would require more than one day for the delivery and return.

Rearing trout to the larger sizes has the additional advantage of getting away from the overcrowding that sometimes occurred in the fry-planting days when hatchery equipment usually was designed to handle a maximum number of eggs in a limited space. Now the hatchery problem is that of finding sufficient room to accommodate the young trout during their early growth. It seems advisable to place them in rearing ponds. I think the reduction of crowding has saved many fish.

It also appears that the rearing of trout to a larger size has been accompanied by the extension of the trout-culturist's duties and responsibilities. The responsibility of planing also is largely in his hands. Formerly the responsibility of the fish-culturist ended when he delivered the fry to the sportsmen at the railway station; now he must see that the fish are properly distributed in the water. We have found it advantageous to assign to each district the responsibility for planting in that district. In that way we avoid the former difficulty of having a certain lake or stream stocked by three or four different agencies, or possibly not stocked at all because each expected the other to do it.

The hatchery man is the production manager in this whole scheme. We in the central office undertake to administer certain phases of the work and the research men are trying to gather facts to guide us, but the factory is after all the hatchery and the rearing station associated with it. As I see it, therefore, the trout-culturist does not need to be too much concerned about the trend toward a more critical attitude with respect to the use of the hatchery products. I think this new critical attitude is fine; it is very much needed. But I believe also that there is going to be an important place for hatchery fish. As I

see the future of trout culture, there is going to be a tremendous demand for the products of our trout hatcheries, but we may change somewhat the manner in which we use them.

MR. JOHN GOTTSCHALK, *Indiana Conservation Department:*

As you all know, the culture of warm-water fish in the last few years has become divided into two fairly divergent methods. First, there is the time-honored and long-established method in which fish are reared in fairly large ponds; but stimulating the growth of natural organisms we try to obtain fish as large as possible. Second is the method of forced artificial feeding, principally of black basses. My experience does not permit me to discuss the second method. In discussing the pond culture of warm-water fish I shall base my remarks on our work in Indiana.

I do not want to give the impression that we think we have solved all phases of the problem of rearing panfish in ponds. In fact, I can speak better of the things we are not doing as well as we should, rather than try to tell you about methods that have proved outstandingly successful.

In recent years we have been making strenuous efforts to solve some of the problems that have been confronting the pond-culturist for a long time. As part of our program we have a research staff working in cooperation with the Zoology Department of Indiana University. While most of their work is in the field, we do call upon them from time to time to work on specific problems within the hatcheries.

Earlier in the day's discussion we were talking about survival in ponds and the fate of all the small fish. A year ago we ran an experiment in artificial feeding in an attempt to work out some method of force-feeding black bass in large rectangular warm-water ponds which we inherited from our predecessors. We worked out an agreement with Swift and Company under which they were to furnish the necessary food—a new product which they were placing on the market. We assigned a member of our lake and stream survey staff to one of our hatcheries for the purpose of taking the necessary counts and weights of the fish, making plankton counts, etc. The experiment gave us some interesting negative information. Unfortunately we received only 200 pounds of feed from Swift and Company, which amount lasted us about 3 weeks. Nevertheless we did obtain some interesting figures on survival. We had six ponds in the experiment. The survival of fry planted and removed at about 3 inches in length ranged from 17 per cent in the pond having the poorest survival to 64 per cent in the pond with the best survival. These figures are dependable, as we had actually counted the fry one by one. As a "byproduct" of counting we found that our average production of fry from the 2½-pound brood fish was about 14,000 per nest. We have no reason to

believe there was more than one spawning of eggs on any particular nest.

In order to get more information on the effectiveness of various kinds of fertilizers we set up an experiment at a new hatchery which had not previously been in operation. In this particular experiment we did not find that the commercial fertilizer was very effective. However, we did get between 500 and 600 fish out of each of two ½-acre ponds, these having been fertilized with the commercial fertilizer. Our best production was obtained with soy-bean meal, which resulted in between 5,000 and 6,000 3-inch fingerlings after about 6 months. The control ponds yielded about 1,000 fish. Unfortunately, we were not able to weigh the fish at that time. A very much greater percentage of the fish in the ponds which produced so few were large, and it is entirely possible that the weight removed from the different ponds was very nearly the same.

At the present time we are using cow manure at the rate of 3 to 8 tons per acre. In order to obtain some idea as to the quantity we ought to use, we secured the cooperation of the local county agricultural agents. We submit to the county agent soil samples and from his report we form some idea as to the nature and quantity of the fertilizer we should apply. Fertilizer is broadcast over the entire bottom about a month before the pond is filled. After the pond is filled and about 2 weeks before the spawning season begins we commence fertilizing with soy-bean meal at a concentration of 50 to 125 pounds per acre per week for a period of 8 to 10 weeks. The amount varies with the locality, of course; some of the hatcheries are located in mucky areas where the pond bottoms themselves contain much humus. It is true also that the water contains more nutrient salts in some hatcheries than in others.

In our fertilization work we try to pollute the ponds as much as possible with fertilizer. Only once did we encounter oxygen deficiency in a pond. We lost a few bluegills 2 years ago, but in general we have not needed to worry about oxygen deficiency. We still need more information, but I believe that soy-bean meal is one of the best fertilizers for use in pond propagation of warm-water fish.

A few things we consider to be extremely important. One of them is the keeping of more accurate records. A few years ago I began to look into the matter of individual records for the hatcheries and was amazed to find that we could not even tell how many fish each hatchery had been rearing. Mr. Culler pointed out that each hatchery presents a specific problem. I will carry that further: Each pond presents a specific problem. Consequently we now have worked out a system for keeping an accurate record of the number of fish of different sizes produced in each pond every year. In an attempt to find the causes for variation we are keeping an accurate record of everything which was done to the pond, and of everything unusual which happened in it during the course of the year. The hatchery foremen keep day books

in which they make notes of occurrences. To our office they submit records concerning fertilization and other operations concerned with managing the pond. Records of this kind are invaluable in practical fish-cultural work.

It is extremely important also to know the cost of fish-hatchery operations. Fish culture would be farther ahead if some semblance of the methods of private enterprise had been followed in the past. We are acquainted to some extent with the manner in which business principles are applied at the world's largest goldfish hatchery at Martinsville, Indiana, where they have constantly had to evaluate their work in terms of profit and loss. Unfortunately much of their procedure is a trade secret and they are very reticent about giving out details lest they fall into the hands of persons who might become competitors.

A few years ago we made an attempt to form some idea as to how our money was being spent. Actually we found that only 45 per cent of the effort, as measured in man power, that goes into the rearing of fish was actually connected with fish culture. Much of it went for such extraneous activities as setting up displays at sportsmen's exhibits, public-contact work, and other substantially unnecessary projects. Fish-rescue work is supported by our hatchery budget and of course a large amount goes for maintenance of the hatchery. We try to make our hatchery property attractive. It takes money to maintain lawns and paint buildings but until we have some idea as to what these various activities are costing we cannot very well tell how successful we are. In a way we are like many farmers. If they set up a proper cost-accounting system they would discard many practices which they inherited from their fathers.

With regard to distribution, we have done away with individual applications. Our conservation officers file requests for their territories. The requests are based on the approximate fishing intensity in each particular territory and the amount of water to be stocked. We have a number of lakes in the northern part of the State and several thousand miles of streams. Each warden or officer is responsible for filing the distribution requests for his particular territory.

We have not made a great deal of progress in disease control. So far we have found the prevention of overpopulation the best way to prevent disease in warm-water ponds. To give you some examples on that particular point, in a certain hatchery one foreman has been in the habit of stocking his ponds, all of them small, with a certain number of breeders every year. We have watched the outcome of this procedure because we know that under ordinary conditions those ponds could never be expected to support anything like the quantity of fry that should be produced by stocking. The first year, that particular hatchery produced 56,000 3- to 5-inch smallmouth black bass in 3 acres of water. The second year he made a slight miscalculation as to the time to take out the 1½-inch fish, and only 17,000 2-inch fish were produced. In the third year he was able to distribute 225,000

smallmouth black bass from these 3 acres, of which approximately 10 per cent were 3 or 4 inches long, while the remaining 90 per cent were about 1½ inches long or longer. The year that we produced only 17,200 fish we had a severe infestation of a number of different external protozoan parasites. Apparently the entire population of all the ponds was affected so that the fish which were able to survive the epidemic did not grow as rapidly as did the fish of the previous year when we took out 56,000. At any rate, we found that wherever we encountered overpopulation we began to have trouble with various diseases.

In Indiana the "figure pressure" has been rather strong. Although we have been able to relieve that pressure to a certain extent, we will have to admit that we are still trying to rear a lot of fish largely for the benefit of the annual report. Of course our hatchery workers have suffered because they have been afraid to try out any new methods of disease control, or as a matter of fact any new kind of method which might result in a significant decrease of production. I have no doubt that "figure pressure" has been relieved in many States and that the foremen are able to use their own initiative in trying to find the answers to these problems.

We have found canned carp successful in the production of channel catfish. Our production of that species is not particularly large consisting of 4- to 7-inch fish in total quantity of 75,000 to 100,000 per year. They eat canned carp readily although it is not conducive to good growth. In Indiana, channel catfish spawn usually during the last 2 weeks in June or sometimes in the first week in July and we take out our entire output at the beginning of September. Thus we have only 6 or 7 weeks in which to grow these fish to from 4 to 7 inches.

We tried using the Wisconsin canned carp for black bass. In a new hatchery which is still in the process of construction we built four experimental feeding ponds in which we plan to raise black bass and panfish. We are using at the present time a mixture of canned carp, dried skim milk, and corn meal. We had trouble trying to get the smaller black bass, from ¾ to 1½ inches long, to eat it. Larger fish, from 2½ to 3 inches, eat it readily. It is still too early to draw conclusions as to the success of this particular experiment. We hope in the future to work out a method of feeding which we can supply to our big shallow-water hatchery ponds.

Vegetation frequently becomes a problem, although there is quite a diversity of opinion as to whether it should be allowed to remain in fish ponds, or removed. We try to "ignore" it but sometimes find that difficult. When we do have a pond so overgrown with various forms of rooted vegetation that it becomes a nuisance, we drain the pond down in the fall and treat it with sodium arsenite. The next spring we use a compost made of aquatic vegetation in the same way that we use cow manure. The weeds and grass are saved as they are cut and put on a compost heap; this is thrown into the pond as a fertilizer.

MR. JOE HOGAN, *Arkansas Game and Fish Commission:*

We all recognize that fish production depends largely upon the fertility of the bottom soil and of the water of the ponds. After our spawning season is over we usually draw down our spawning ponds and restock them with assorted fingerlings. Our latest development along this line has been to purchase a pump. When the pond draining is begun, the first pond is emptied through the sewer and all the remaining ponds in succession are pumped dry, the water being lifted from the pond and placed back into the supply lines and used again, thus saving the dissolved nutrients and plankton that remain from our earlier fertilizing work. In other words, if we use 1,000 pounds of fertilizer early in the season to produce *Daphnia* in a pond, most of this fertilizer is saved by the plan of lifting the water from one pond to another. We believe this plan is worthy of consideration. Of course, it is possible that there may be a heavy infestation of parasites which would spread to the new ponds. If so it would be better to use fresh water to refill the ponds.

Fish salvage in Arkansas is very important. More fish could be produced by a systematic salvage program than could be reared in ponds. Large flat-bottomed land areas are found in sections of Arkansas along the rivers. Many "borrow pits" and old oxbows along the levees and rivers retain water early in the season but eventually become dry and result in the loss of many fish. A good salvage program integrated with the hatchery distribution system is worth considering.

MR. GOTTSCHALK:

I failed to mention one thing; the distribution throughout the State. To us the 10-gallon milk can is a "curse and damnation", but we have not been able to find any really satisfactory method of replacing it. Most trucks with a circulation or aerating system will carry too many fish for any one of our hatcheries. I would certainly be glad to receive suggestions on an economical method of distributing fish in small quantities over large areas. When we transfer fish from one hatchery to another, 50,000 or 100,000 at a time, we have no trouble because we use aerating units, but when we make 50 or 60 isolated plantings of a few hundred fish each we have trouble.

DR. EDWARD SCHNEBERGER, *Wisconsin Conservation Department:*

With the cooperation of Dr. Chancey Juday of the Wisconsin Geological and Natural History Survey, we attempted some fertilization experiments. The first one was with phosphates. The phosphate was suspended in bags in an anchored floating construction of logs. Second, we tried lime which we broadcast around the shore. Later soy-bean meal was tried. It has been some time since I have gone over the re-

sults, but the production of zooplankton and phytoplankton was increased by all three types of fertilization.

One lake with which we experimented contained only two species of fish—yellow perch and smallmouth black bass. At the beginning of the experiment the yellow perch were predominant, and shortly afterward the black bass were the more numerous. Just what the present status is I do not know although the observations are being continued.

I have listened with a great deal of interest to the discussion of artificial versus natural propagation and reproduction. Wisconsin supports an extensive program of artificial propagation. I think the keynote was struck by Mr. Rodd when he stated that we should determine the deficiencies of nature, operating on the premise that each area presents its own problem. We are faced particularly with the problem of trying to evaluate the natural reproduction of wall-eyed pike. Two lakes were selected for this study. In one lake there seemed to be a considerable loss of the eggs from wave action that actually piles up windrows of eggs along the shore. In the other lake the spawning area was of a different nature, having a bottom of gravel and even rocks. I believe that efforts to standardize such evaluations should be considered. In our studies we tried to determine the number of eggs that were deposited, the percentage of fertility, the number of eggs that hatched into fry, etc. Of course, as soon as the eggs hatched our problem became exceedingly difficult, and we were unable to recapture many of the fry. Our results are not fully tabulated to date, so that I cannot give you any details.

Another important problem is the silting of streams. The prevention of silting is related to the forestry program in Wisconsin. We are trying to give the forests a chance to recover by reduction of fire losses. We also do some planting. This program has given many of our trout streams colder water and a slower run-off. In the southern part of the State, which is largely agricultural, reforestation is not as easy to carry out. I believe that it will be necessary to obtain title to the southern streams by actually buying a strip of land along the stream and then making a planting and fencing the stream off so that the cattle will not destroy the plantings. I imagine everyone has seen examples of a good trout stream about 3 feet wide and 1½ feet deep transformed by cattle into a stream that is 8 or 10 feet wide and 2 inches deep.

APPENDICES

AMERICAN FISHERIES SOCIETY

Organized 1870

CERTIFICATION OF INCORPORATION

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certifying in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interest of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

SEYMOUR BOWER	(Seal)
THEODORE GILL	(Seal)
WILLIAM E. MEEHAN	(Seal)
THEODORE S. PALMER	(Seal)
BERTRAND H. ROBERTS	(Seal)
HUGH M. SMITH	(Seal)
RICHARD SYLVESTER	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

OF THE

AMERICAN FISHERIES SOCIETY

(As Amended August 26, 1942)

ARTICLE I

NAME AND OBJECT

The name of this Society shall be American Fisheries Society.

The objects of this Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

ARTICLE II

MEMBERSHIP

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may upon payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privileges of active membership for the duration of his life.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2.00) dollars per year.

State Memberships.—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State memberships shall be twenty ($20.00) dollars per year.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the President of Mexico, the Governors of the several states, and the Secretary of the Interior of the United States, the Governor-General of Canada, the Lieutenant-Governors of the several Canadian provinces, and the Dominion

Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

Election of Members between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

Rights and Duties of Members.—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues.

Transactions.—Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of *Transactions*. Only members in good standing may present papers either by reading or by title at the annual meetings and publish them in the *Transactions;* except that outstanding non-members invited by the President of the Society to participate in the program shall be exempted from this requirement. No member may have listed on the program of an annual meeting, or present, or have published in any one volume of the *Transactions* more than two papers; and for purposes of this rule joint authorships shall compare equally with sole authorships.

Quorum.—Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests, and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary. The Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings. A majority of the Executive Committee shall constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee, except the members of the Committee on Common and Scientific Names of Fishes.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed *Transactions*, and shall have charge of the sale of surplus copies of such *Transactions*.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting, placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

ARTICLE V

Standing Committees

The standing committees shall be Executive; International Relations; State and National Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by Article IV.

The Committee on International Relations shall be composed of seven members selected by the nominating committee for election, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fishery biologists, conservation and fishery administration officials, fish-culturists or aquicultural societies. A report based on such exchange should be presented at each regular meeting.

The Committee on State and National Relations shall be composed of five members selected by the nominating committee for election, and its duties shall be to act in behalf of the Society as a coordinating and advisory board for the

*The Council was discontinued and the Executive Committee enlarged by Amendment to By-Laws, September 11, 1935.

consideration of interstate and National-State fishery problems. A report shall be presented at each annual meeting.

The Committee on Common and Scientific Names of Fishes shall be composed of seven members selected by the nominating committee for election. Its duties shall be to establish and maintain in the files of the Librarian of this Society a correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

ARTICLE VI

Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

ARTICLE VII

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
   a. President
   b. Secretary
   c. Treasurer
   d. Vice-Presidents of Divisions
   e. Standing Committees
   f. Special Committees
5. Committees appointed by the President:
   a. Committee of five on nomination of officers and standing committees for the ensuing year.
   b. Committee of five on time and place of next meeting.
   c. Committee of five on resolutions.
   d. Auditing committee of three.
   e. Committee of three on program.
   f. Committee of three on publicity.
   g. Committee of five on publications.*
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

ARTICLE VIII

Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at leas twenty-five members are present at said regular meeting.

*A resolution adopted August 24, 1937 established a staggered committee of five and provided that each incoming President shall appoint one new member for a term of five years and designate the Chairman of the Committee.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

(Showing year of election to membership)

HONORARY MEMBERS

The President of the United States.
The President of Mexico.
The Secretary of the Interior of the United States.
The Governors of the several States.
The Governor-General of Canada.
The Lieutenant-Governors of the several Canadian Provinces.
The Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'04 Denbigh, Lord, London, England.
'40 Gordon, Seth, % Game Commission, Harrisburg, Pa.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 California Barrel Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore & Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware & Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.

'15 Puget Sound Navigation Co., Seattle, Wash.
15 Ray, W. S. Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wis.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'04 Coker, Dr. Robert E., University of North Carolina, Chapel Hill, N. C.
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'28 Hall, W. A., Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
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'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
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'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina, S. A.
'22 Walcott, Frederic C., Norfolk, Conn.
'98 Ward, Dr. Henry B., 1201 Nevada St., Urbana, Ill.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

ACTIVE MEMBERS

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'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
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'31 Aldrich, A. D., P. O. Box 1365, Tulsa, Okla.
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'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
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'26 Alm, Dr. Gunnar, Commissioner of Fresh-water Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
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'39 Anderson, David, Okemos, Mich.
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'40 Carpenter, Ralph G., 2nd, Wolfeboro, N. H.
'41 Carr, Harold B., U. S. Fish and Wildlife Service, Washington, D. C.
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'23 Davis, Dr. H. S., U. S. Fish and Wildlife Service, Kearneysville, W. Va.
'39 Davis, Lyle Lavern, Brady, Tex.
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'38 Faulkner, Luther W., High St., Chelmsford Center, Mass.
'28 Fearnow, Theodore C., Berkeley Springs, W. Va.
'41 Feast, C. N., Game and Fish Dept., Denver, Colo.
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'32 Fiedler, R. H., U. S. Fish and Wildlife Service, Washington, D. C.
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'34 Griffiths, Francis P., Oregon State Agricultural College, Corvallis, Ore.
'31 Grim, D. N., Hawley, Pa.
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'34 Haskell, David C., Rome, N. Y.
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'11 Pohoqualine Fish Association, Charles C. Townsend, Sec., Provident Trust Bldg., Philadelphia, Pa.
'21 Porter's Lake Hunting and Fishing Club, Fred W. Wagner, Sec., 925 West Huntington St., Philadelphia, Pa.
'39 Province of Quebec Association for the Protection of Fish and Game, Inc., E. A. Cartier, Sec., 1154 Beaver Hall Sq., Montreal, Canada.
'30 Seigniory Club, J. L. Jorgensen, Supt. of Fisheries, Box 54, Montebello, P. Q., Canada.
'35 Sharon Fish and Game Club, Inc., G. H. Fecitt, Sec., East Street, opp. Billings, Sharon, Mass.
'41 Sixteen Island Lake Fishing Club, Inc., F. M. Scott, Secy.-Treas., Aldred Bldg., Montreal, Canada.
'35 Smith Bros., Port Washington, Wis.
'25 Southside Sportsmen's Club, Oakdale, L. I., N. Y.
'37 United Fishermen's Union of the Pacific, 212 West 6th St., San Pedro, Calif.
'26 U. S. Fisheries Association, 196 Water St., New York, N. Y.
'37 Valley City Milling Company, Portland, Mich.
'38 Von Hoffman Press Club, 101 South 9th St., St. Louis, Mo.
'28 Weber Lifelike Fly Co., Stevens Point, Wis.
'39 Western Bass Club, 222 Broadway North, Seattle, Wash.

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'40 Department of Agriculture and Fisheries, Bangkok, Thailand.
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'39 Conservation Regional Districts No. 2, Norwalk, Ohio.
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'39 Conservation Regional Districts No. 4, Cambridge, Ohio.
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'37 Fisheries Section, Fisheries Reservation, Cronulla, New South Wales.

'37 Fishery Research Institute, P. O. Box 728, St. John's, Newfoundland.
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'10 Stead, David G., Watson Bay, New South Wales, Australia.

INSTRUCTIONS FOR PREPARING AND EDITING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1941)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your editorial committee (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Manual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced.** Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case, do not use all capital letters for any purpose and underscore only when italics are intended.

2. **Carbon copies will not be accepted.** Do not use thin, transparent paper. Heavy bond paper is preferred.

3. **Margins** at top, bottom, and both sides should be about 1½ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages** must be numbered in consecutive order, including the bibliography, tables, charts, and photographs. Tables, charts, and all illustrations must be inserted near their place of reference in the text.

5. **Illustrations.** Make separate pages of tables with headings (not of leader work), of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, figures, maps, charts, and tables, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the

text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. **The title** of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use the word "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer:

REPORT ON THE DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any references not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN.
1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., 1938, Vol. 68, pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. **Tables.** Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length in millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

12. **Capitals.** Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Boulder Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but lower-case a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher orders.

13. **Abbreviations.**

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures—F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

"*Number*," when preceding figures—No. 125; otherwise spell out.

"*United States*," if preceding name of a department or a bureau or a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana*.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5-September 2.

Measures and weight, except p.p.m.—6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage—12 per cent, a percentage of 25.5.

14. **Numerals.** Spell out all *isolated* numbers less than 10, but use figures in a grounp of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance (if fraction spell out, as one-half mile), clock time, time, money, percentage, degrees, proportion or ratios, age, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; about 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes at 30

minutes past 4 o'clock; 25.5 per cent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938, the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require use of the hyphen when used as adjectives. For example note the following sentences: "This was *cold water.*" "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, direct, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.** Do not expect your Editorial Committee to rewrite your manuscript.

17. **Be definite in references to species.** The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," "trout," "pike," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. **Things to avoid.** Words that do not appear in the dictionary in the sense employed should be avoided. The *words* "ease," "instance," "show," "found," "gave," and "present" are overworked in manuscripts, the same word sometimes appearing several times in one paragraph.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives.* Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every *case.*" "*The mortality was high* in every *pond.*"

19. **Abstract of paper.** Give a condensed summary or brief abstract at the beginning of your paper.

Prepared by the Committee on Publications.
February, 1937 (revised 1941).

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